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VOLUME 57 JULY 1971 NUMBER 3

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SENSITIVITY OF STRIPED BASS AND STICKLEBACK TO AMMONIA IN RELATION TO TEMPERATURE AND SALINITY[1]

CHARLES R. HAZEL, WALTER THOMSEN, and STEPHEN J. MEITH
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Water Pollution Control Laboratory

Toxicity of undissociated NH_4OH to striped bass (*Morone saxatilis*) and stickleback (*Gasterosteus aculeatus*) was determined by static bioassay at 15 C and 23 C in freshwater, 33% seawater, and seawater. The 96-hr median tolerance limits (TLm) of striped bass in mg/liter NH_4OH were as follows: at 15 C—freshwater 2.8, brackish water 2.8, and seawater 2.0; at 23 C—freshwater 1.9, brackish water 2.1, and seawater 1.5. The 96-hr TLm of sticklebacks were: at 15 C—freshwater 2.1, brackish water 5.2, and seawater 10.4; at 23 C—freshwater 1.8, brackish water 2.4, and seawater 2.3.

The influence of salinity and temperature on the toxicity of undissociated ammonia was less for striped bass than for sticklebacks; or, sticklebacks were more resistant to ammonia poisoning at the higher salinities and the lower temperature. Striped bass were slightly more tolerant in brackish water than in freshwater or seawater.

INTRODUCTION

As a result of difficulties encountered in setting waste discharge requirements for undissociated ammonia, it was apparent that more technical data were needed, especially in reference to bioassay methods and striped bass.

In the past, bioassay for or measurement of ammonia toxicity have been done using a variety of methods and test species. Sticklebacks are commonly used in the San Francisco Bay region. Considering that striped bass are the principal sport fish in the bay, a question that often arises is: How does the sensitivity to ammonia of the striped bass compare to that of the stickleback? Also, how do temperature and salinity affect these sensitivities? We have attempted to answer these questions at least partially in this report.

Evidence points out that in ammonia poisoning the concentration of undissociated ammonia at the gill surface determines toxicity (Wuhrmann and Woker, 1948). Ammonia toxicity may be influenced by other toxic or physiologically regulating substances present at the gill such as oxygen (Downing and Merkens, 1955) and heavy metals (Herbert and Vandyke, 1964; Herbert, 1965). Carbon dioxide (Lloyd and Herbert, 1960) affects level of toxicity by influencing the degree of dissociation of ammonia at the gill. Salinity was shown by Herbert and Shurben (1964) to influence the resistance of rainbow trout to ammonia. Yearling rainbow trout were most resistant to ammonia toxicity in about 30% seawater as compared to freshwater and seawater. Apparently eggs are more resistant than fry or fingerlings (Penaz, 1967).

[1] Accepted for publication February 1971. Work on this project was supported in part by Federal Water Pollution Control Administration Purchase Order Number 81-0622.

There is some difference in sensitivity between species (Ball, 1967). The 96-hr TL*m* values for five species, including trout, were found by Ball to be between 0.29 and 0.41 mg/liter undissociated ammonia nitrogen (0.72–1.02 mg/liter NH_4OH). These values fall in the TL*m* range of 0.4 and 1.2 mg/liter undissociated NH_4-N reported by McKee and Wolf (1963). Because of the many ways of reporting concentrations of ammonia and of performing bioassays, it is difficult to compare results reported in all but a few papers.

During the time we were doing this work, attempts were made to gather information on those aspects of bioassay methods and interpretation of chemical analyses that tend to influence the reported results of such tests.

METHODS AND MATERIALS

Bioassay

Static bioassay tests were conducted in a manner generally in accordance with the method given in 12th Ed. of *Standard Methods for the Examination of Water and Wastewater* (A.P.H.A., et al. 1965) during the period June 26 to October 28, 1969.

Test Fish

Striped bass and three-spined sticklebacks were used as test fish. Striped bass were "young-of-the-year" fish ranging from about 20 mm TL in June to 93 mm TL in October. Sticklebacks were juvenile to adult, ranging from 32 to 60 mm TL.

Striped bass were collected from screening facilities at the U.S. Bureau of Reclamation and State Department of Water Resources fish rescue facilities near Tracy. Sticklebacks were taken in minnow traps at Berkeley Aquatic Park, Berkeley, and by dip net in Kentwood Creek, at Kentfield, Marin County.

All fish were acclimatized for one or more days prior to testing to the temperature and salinity at which they were tested.

The number of fish per test container varied from 5 to 25 depending on the size of the fish available. Most tests were run with 10 fish per jar. Variation in number used was necessary to keep a favorable ratio of fish weight to volume of test solution.

Test Solutions

Tests were run in freshwater, 33% seawater, and seawater. The source of salt water was filtered seawater from Steinhart Aquarium, San Francisco. Brackish water consisted of $\frac{1}{3}$ seawater and $\frac{2}{3}$ filtered American River water. Freshwater used in stickleback tests was filtered American River water with a hardness of 25–30 mg/liter $CaCO_3$, but that used in striped bass tests was water from the fish facilities at Tracy which has a hardness of 150–200 mg/liter $CaCO_3$. The latter was strained and settled prior to use. Tracy water was used in striped bass tests because of the death of some of these fish in controls and acclimatization tanks with American River water. Striped bass in the size range 20–50 mm do not survive well in American River water with a hardness of 25–30 but do quite well if salts are added.

Bioassays were run in 20-liter capacity glass jars filled to 10 liters. The concentrations of ammonia in these jars were formulated accord-

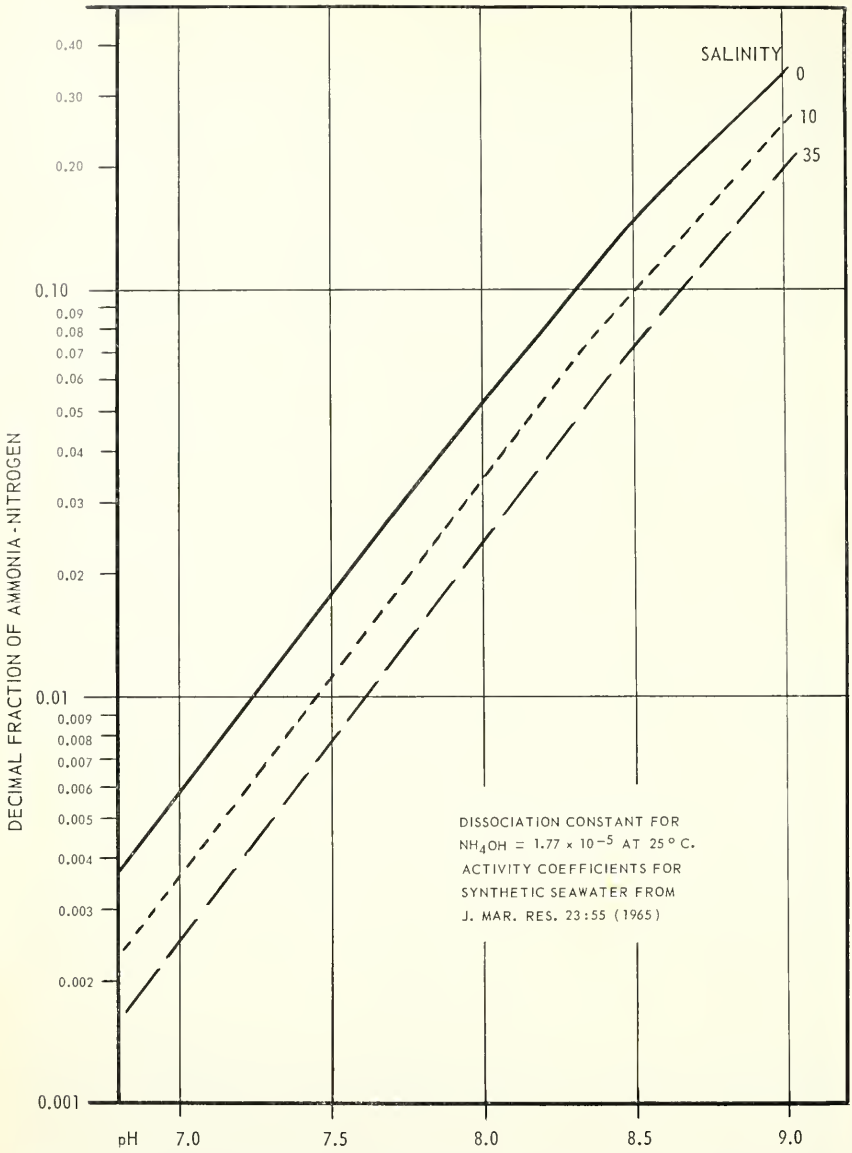

FIGURE 1. Relationship between pH, salinity, and decimal fraction of undissociated ammonia-nitrogen, ammonia, or ammonium hydroxide at 25 C. (Redrawn from R. E. Kreider, Laboratory Report, Standard Oil, Richmond Refinery, March 11, 1968.)

ing to the following rationale: the concentration of undissociated ammonia in solution is dependent on pH, salinity, temperature, and total concentration of ammonia. The higher the pH, the greater the undissociated fraction. Because pH varies greatly in water containing fish, the actual concentration of undissociated ammonia also varies. Ammonia is volatile and subject to biological consumption, which influence concentration with time. For these reasons, the initial concentration of the undissociated fraction cannot be easily maintained or predicted throughout the test period. Consequently, actual concentrations of NH_4-N were determined by analysis during the tests.

A source of confusion in work with ammonia toxicity is associated with the nomenclature of the toxic form of ammonia. Two designations of the toxic form occur in this paper: (i) nondissociated ammonia nitrogen, and (ii) ammonium hydroxide. Ammonium hydroxide is relied on most frequently, because it is quickly recognized as ammonia in its nondissociated toxic form. However, values are also given in terms of nondissociated ammonia nitrogen for purposes of comparison.

As previously pointed out, the concentration of the toxic form of ammonia in solution is influenced by pH, temperature, and salinity. To at least partially compensate for the effect of salinity on the dissociation of ammonia a graph was used that correlates degree of dissociation to pH and salinity (Figure 1). These relationships were prepared by R. E. Kreider of the Standard Oil Company of California, Richmond, California, (pers. comm.) from the dissociation constant of ammonimum hydroxide at 25 C and activity coefficients for synthetic seawater. A basic assumption in this case is that the activity coefficients of all ions in a solution decrease as ionic strength increases. Unfortunately, information was not available to work out such relationships for 15 C, thus the 25 C chart was used for both the 15 C and 25 C tests. In any case the use of the chart in Figure 1 is considered more appropriate for tests done in saline waters than reliance on just the dissociation constant of ammonia in distilled water at 25 C.

Test solutions were prepared by the quantitative addition of a stock solution of ammonium chloride (0.25 g/ml) to each test container. The volume in milliliters of stock solution made up to 10 liters of test solution was determined by use of the following formula:

$$\text{ml of stock } NH_4Cl = \frac{NH_4OH\ (1.5267)}{25F}$$

where: NH_4OH = concentration in mg/liter of undissociated NH_4OH wanted

1.5267 = equivalents constant

F = fraction of undissociated NH_4OH at the pH and salinity of test solution (see Figure 1)

25 = factor based on stock solution of 0.25 g/ml NH_4Cl and test solution of 10 liters

Initial "F" values were chosen as follows:

Type Water	*Assumed pH*	*F*	
Fresh	7.5	0.0175	
Brackish	7.5	0.0100	(or 0.008 when the amount of stock solution added was more than 2 ml)
Sea	8.0	0.0250	

For purposes of formulating initial test solutions, the values of pH shown above were assumed to be those present during the test; the real values were approximated by these assumed values.

Aeration was used only when necessary to maintain adequate levels of dissolved oxygen (D.O.), that is, when D.O. was lowered to about 5.0 mg/liter. A number of the tests on sticklebacks and those with the larger (93 mm) striped bass required aeration. Filtered air was supplied from a compressor with oil-free pistons and was introduced at a low rate to solutions through plastic hoses terminating with air dispersal stones.

Tests were conducted at 15 C (59 F) and 23.3 C (74 F). A few of the replicate tests were conducted at 17 C (63 F) instead of 15 C. Temperature was controlled by maintaining a constant room temperature. All water used was brought to the proper temperature prior to start of tests.

Criteria of Mortality

Daily observations were made of the number of fish dead in each test solution. All dead fish were immediately removed. Fish were recorded as dead when they appeared to have lost all ability to move or respond to stimuli. In two cases where mortality exceeded 10% in the controls, Abbott's (1925) correction for natural mortality was applied to the other observed mortalities in that test before graphical computations of the TL*m*. Although such tests are not considered as valid in *Standard Methods* . . . (A.P.H.A., 1965), they were thought significant and the results were included in this study.

Chemical Analyses

The concentration of dissolved oxygen and pH were determined at the start of each test and daily thereafter when possible. These parameters were measured using a Weston and Stack Dissolved Oxygen Analyzer and a Beckman Model-N pH meter.

Concentrations of ammonia nitrogen (NH_4-N) were estimated by direct nesslerization using a modification of the procedure given in *Standard Methods* . . . (A.P.H.A., 1965). Differences were that in brackish water and seawater no zinc sulfate was added. Four-tenths ml of 6.25 N sodium hydroxide was added to 10 ml of sample, mixed, and centrifuged to remove insoluable hydroxides. An aliquot of the supernatant, usually 0.3 to 3.0 ml, was diluted to 50 ml with deionized water. After addition of 1 ml of Nessler's reagent and a 10–15 min. wait, absorbance was measured at 410 mμ with a slit width of 1.205 mm, using a Beckman Model DBG spectrophotometer.

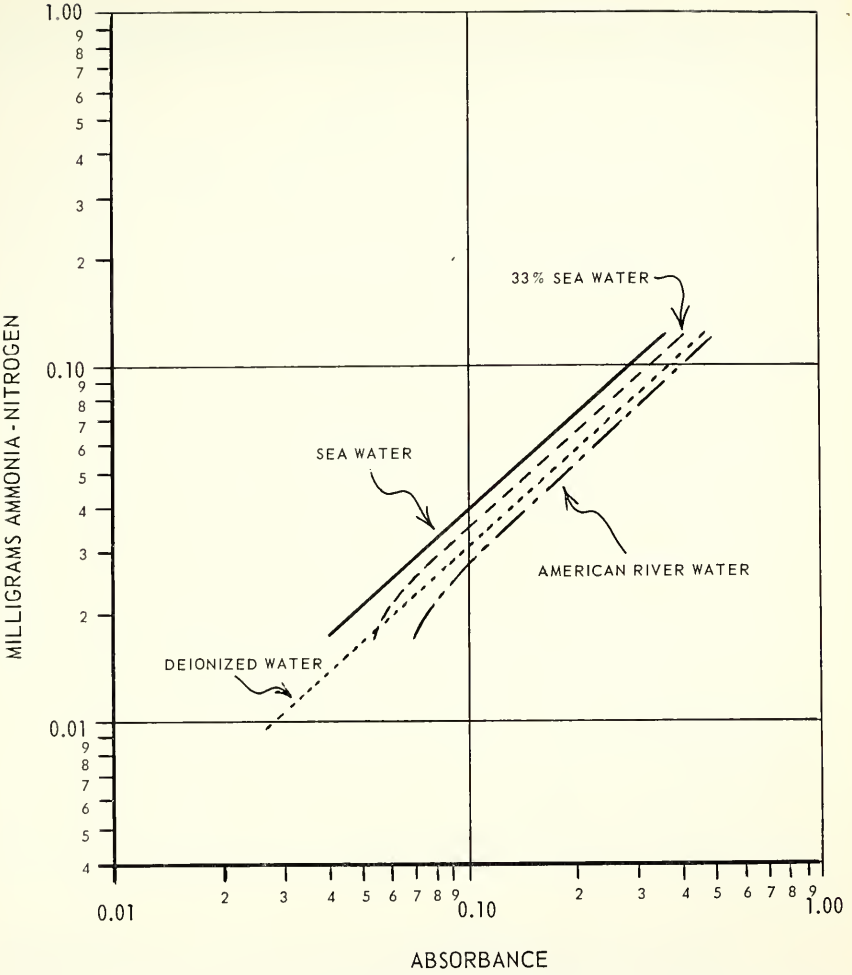

FIGURE 2. Concentration of ammonia-nitrogen versus absorbance as observed in standard solutions using seawater, 33% seawater, American River water, and deionized water as diluents.

In freshwater the *Standard Methods* . . . (ibid.) procedure was followed, except that no EDTA was used. Standard curves used in the estimation of NH_4-N are included as Figure 2.

To obtain an idea of the accuracy of the method, a recovery experiment was performed. Known amounts of ammonia nitrogen were added to aliquots of water samples taken from freshwater, 33% seawater, and seawater aquaria which contained fish. After mixing in a known quantity of NH_4-N, analyses were made by the usual method. The results are tabulated in Table 1. Control values are the amounts of NH_4-N that were present before additions were made. NH_4-N was added to give the quantities noted as "expected". The "observed" values are the measured concentrations. There was no measurable difference between

TABLE 1. **Results of Addition of Increasing Amounts of NH_4-N to Freshwater, 33% Seawater, and Seawater Taken From Bioassays Control Aquaria Which Contained Fish for the Previous 96 Hr.**

	Freshwater			33% Seawater			Seawater		
Sample	Observed mg/liter	Expected mg/liter	(Observed-expected)	Observed mg/liter	Expected mg/liter	(Observed-expected)	Observed mg/liter	Expected mg/liter	(Observed-expected)
Control	14.67	14.67	0.00	21.00	21.00	0.00	29.33	29.33	0.00
1	17.00	16.67	0.33	25.00	24.00	1.00	32.67	31.33	1.34
2	19.00	18.67	0.33	28.00	27.00	1.00	37.00	32.67	4.33
3	20.67	20.67	0.00	32.00	30.00	2.00	37.00	35.33	1.67
4	23.00	22.67	0.33	35.00	33.00	2.00	39.00	37.33	1.67
5	24.67	24.67	0.00	38.50	36.00	2.50	42.00	39.33	2.67
6	26.00	26.67	−0.67	43.00	39.00	4.00	44.00	41.33	2.67
Mean	21.72	21.70	0.02	33.58	31.50	2.08	38.61	36.22	2.39

expected and observed concentrations in freshwater. However, in brackish water and seawater a difference was found and it tended to increase slightly with increasing concentration; and observed values were 4 to 10% greater than those expected. If these trends are real, then the reported TL*m*'s in 33% seawater and seawater are biased and too high rather than low.

RESULTS

Over 30 bioassays yielding 12 TL*m* values for sticklebacks and 15 for striped bass were performed. The toxicity relationship between these two species, as influenced by temperature, salinity, and the concentration of undissociated ammonia, was thus defined. Median tolerance limits derived from these tests are given in Table 2.

Summaries of those data used in graphical computations of TL*m* values are given in Tables 3 through 8. Where number of analyses were four or five, a Standard Deviation was computed, and in the case of estimates of undissociated NH_4OH 95% confidence limits were also recorded. If confidence limits were not computed, the range was listed instead.

TABLE 2. **Ninety-six Hr Median Tolerance Limits in mg/liter Undissociated Ammonium Hydroxide for Stickleback and Striped Bass at 15 and 23 C in Freshwater, 33% Seawater, and Seawater.**

	Freshwater		33% Seawater		Seawater	
	15°	23°	15°	23°	15°	23°
Stickleback	1.5 2.7	1.5 2.2	7.1 3.2	1.8 2.9	10.5 10.3	2.4 2.2
Mean	2.1	1.8	5.2	2.4	10.4	2.3
Striped bass	1.9 --- 3.7	1.4 2.4 ---	2.8 2.6 3.1†	2.8 1.8 1.8*	1.5 2.5† ---	1.4 1.7* ---
Mean	2.8	1.9	2.8	2.1	2.0	1.5

* Test terminated at 72 hr.
† Test run at 17 C.

TABLE 3. **Results of Static Bioassay of Striped Bass in Ammonium Chloride With a Freshwater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_4-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 40–68									
Freshwater at 15 C.									
10	5	40.33	2.13	7.36	0.12	1.31	0.37	0.89–1.73	
80	5	67.90	3.88	7.36	0.08	2.21	0.50	1.64–2.78	1.9
100	2	119.50	--	7.33	--	3.58	--	(3.05–4.10) *	
Bioassay no. 50–68									
Freshwater at 15 C.									
0	5	27.10	0.82	7.80	0.24	2.50	0.90	0.19–4.81	
80	5	42.20	0.84	7.87	0.24	4.47	0.80	2.85–6.09	3.7
Bioassay no. 41–68									
Freshwater at 23 C.									
60	5	42.40	4.36	7.41	0.13	1.45	0.53	0.84–2.06	
100	2	67.50	--	7.39	--	2.36	--	(1.87–2.85)	1.4
Bioassay no. 49–68									
Freshwater at 23 C.									
12.5	5	17.50	2.50	7.86	0.21	1.84	0.66	1.08–2.60	
100	2	25.25	--	8.00	--	3.73	--	(2.19–5.27)	2.4

* Range in lieu of confidence limits.

TABLE 4. **Results of Static Bioassay of Striped Bass in Ammonium Chloride With 33% Seawater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_4-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 21–68									
33% Seawater at 15 C.									
40	2	50.00	--	7.72	--	2.06	--	(2.00–2.12) *	
61	2	73.50	--	7.72	--	3.02	--	(2.81–3.24)	2.6
100	2	96.50	--	7.73	--	4.08	--	(3.83–4.32)	
Bioassay no. 31–68									
33% Seawater at 15 C.									
0	5	73.45	4.47	7.62	0.16	2.45	0.36	2.04–2.86	
100	2	106.50	--	7.56	--	3.19	--	(2.01–4.55)	2.85
Bioassay no. 48–68									
33% Seawater at 15 C.									
0	4	71.88	7.60	7.54	0.28	2.22	1.21	0.66–3.78	
100	2	142.00	--	7.57	--	4.34	--	(3.00–5.32)	3.1†
Bioassay no. 19–68									
33% Seawater at 23 C.									
34	2	42.00	--	7.59	--	1.33	--	(1.20–1.46)	
86	2	67.00	--	7.72	--	2.88	--	(2.20–3.56)	1.8
Bioassay no. 34–68									
33% Seawater at 23 C.									
0	5	42.40	2.68	7.73	0.10	1.85	0.42	1.37–2.33	
75	5	72.80	2.28	7.70	0.12	3.01	0.64	2.27–3.75	2.8
100	2	158.00	--	7.60	--	5.52	--	(3.04–8.01)	
Bioassay no. 46–68									
33% Seawater at 23 C.									
0	2	24.75	--	7.95	--	2.19	--	(1.58–2.81)	
30	4	43.12	4.80	7.64	0.37	1.60	0.97	0.35–2.85	1.8†
100	2	65.75	--	7.66	--	2.80	--	(1.27–4.34)	

*Range in lieu of confidence limits. † Test ended at 72 hr.

TABLE 5. **Results of Static Bioassay of Striped Bass in Ammonium Chloride With a Seawater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_4-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 32–68									
Seawater at 15 C.									
20	5	13.03	2.42	8.06	0.13	0.95	0.28	0.63–1.27	
40	5	19.61	2.49	8.08	0.12	1.53	0.27	1.22–1.84	
90	5	31.96	3.98	8.12	0.08	2.62	0.46	2.09–3.15	1.5
100	2	50.75	--	8.12	--	4.15	--	(3.77–4.54) *	
Bioassay no. 47–68									
Seawater at 15 C.									
0	3	17.50	--	7.94	--	0.98	--	(0.66–1.25)	
37.5	4	32.50	3.18	7.99	0.07	2.05	0.48	1.49–2.61	2.5†
37.5	4	51.38	11.01	7.94	0.05	2.77	0.84	1.93–3.61	
Bioassay no. 35–68									
Seawater at 23 C.									
50	5	11.35	0.20	8.18	0.20	1.07	0.46	0.54–1.60	
37.5	5	19.87	0.38	8.08	0.19	1.56	0.61	0.86–2.26	
87.5	5	31.70	1.44	8.12	0.16	2.66	0.89	1.69–3.63	1.4
100	2	56.00	--	8.04	--	5.72	--	(2.75–8.70)	
Bioassay no. 45–68									
Seawater at 23 C.									
0	3	13.17	--	8.23	--	1.33	--	(0.96–1.57)	
25	4	19.16	4.10	8.08	0.16	1.53	0.53	0.92–2.14	1.7†
100	2	30.25	--	8.00	--	2.04	--	1.36–2.71	

* Range in lieu of confidence limits. † Bioassay ended at 72 hr.

TABLE 6. **Results of Static Bioassay of Stickleback in Ammonium Chloride With a Freshwater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_4-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 25–68									
Freshwater at 15 C.									
0	3	102	--	7.20	0.00	2.29	--	(2.21–2.34) *	
60	3	142	--	7.10	0.08	2.74	--	(2.39–3.38)	2.7
Bioassay no. 29–68									
Freshwater at 15 C.									
40	4	110	28.14	6.80	0.11	1.04	0.49	0.41–1.67	
80	4	157	34.21	6.80	0.00	1.37	0.30	0.98–1.76	
80	4	197	121.70	6.82	0.04	1.83	0.35	1.38–2.28	1.5
100	4	263	141.70	6.79	0.02	2.27	0.56	1.55–2.99	
Bioassay no. 17–68									
Freshwater at 23 C.									
0	3	--	--	7.18	--	1.13	--	(0.55–2.09)	
100	3	--	--	7.01	--	2.01	--	(0.75–3.13)	1.5
Bioassay no. 55–68									
Freshwater at 23 C.									
20	3	71	--	7.26	--	1.97	--	(1.53–2.22)	
100	3	126	--	7.24	--	3.15	--	(2.79–3.78)	2.2

* Range in lieu of confidence limits.

TABLE 7. **Results of Static Bioassay of Stickleback in Ammonium Chloride With a 33% Seawater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_3-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 23–68									
33% Seawater at 15 C.									
0	2	118	--	7.67	--	2.47	--	(1.65–3.30) *	
40	2	116	--	7.38	--	3.18	--	(2.37–3.99)	3.2
Bioassay no. 26–68									
33% Seawater at 15 C.									
0	4	76	5.25	7.97	0.12	5.79	1.69	3.62–7.96	
100	2	147	--	7.85	--	8.69	--	(5.76–11.63)	7.1
Bioassay no. 18–68									
33% Seawater at 23 C.									
0	2	74	--	7.55	--	1.88	--	(1.79–1.98)	
60	2	60	--	7.59	--	2.12	--	(1.93–2.31)	1.8
Bioassay no. 52–68									
33% Seawater at 23 C.									
0	3	42	--	7.75	--	1.97	--	(1.28–2.59)	
50	3	71	--	7.70	--	2.89	--	(2.28–3.38)	2.9
100	2	150	--	7.58	--	4.50	--	(4.38–4.62)	

* Range in lieu of confidence limits.

TABLE 8. **Results of Static Bioassay of Stickleback in Ammonium Chloride With a Seawater Diluent. Results Are Those Used in Graphical Computation of the 96-Hr TLm.**

Percent mortality	Analytical results NH_3-N in mg/liter			pH		Estimated undissociated NH_4OH in mg/liter			TLm 96
	No.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	95% C.L.	
Bioassay no. 27–68									
Seawater at 15 C.									
0	4	88	19.18	8.18	0.13	8.43	3.09	4.46–12.40	
100	3	105	--	8.24	--	12.14	--	(5.88–15.69) *	10.3
Bioassay no. 28–68									
Seawater at 15 C.									
0	4	96	27.9	8.13	0.10	8.28	4.16	2.93–13.63	
20	4	134	46.1	8.09	0.07	10.43	4.38	4.80–16.06	10.5
80	4	188	109.1	8.06	0.05	10.89	4.66	4.90–16.88	
Bioassay no. 20–68									
Seawater at 23 C.									
0	2	56	--	7.93	--	2.06	--	(1.64–2.48)	
100	2	68	--	7.94	--	2.97	--	(1.74–4.20)	2.4
Bioassay no. 53–68									
Seawater at 23 C.									
10	3	16	--	7.95	--	1.21	--	(0.70–1.83)	
30	3	29	--	7.99	--	2.11	--	(1.23–3.00)	2.2
100	2	50	--	7.98	--	2.36	--	(3.13–3.96)	

* Range in lieu of confidence limits.

The relationships between temperature and salinity and TL*m's* in mg/liter NH_4OH are illustrated in Figures 3 and 4 for both species. At 15 C, sticklebacks were decidedly more tolerant of NH_4OH poisoning in brackish water and seawater than they were at 23 C; however, there was little difference in freshwater. Striped bass were slightly more tolerant at 15 C and in 33% seawater than they were at the

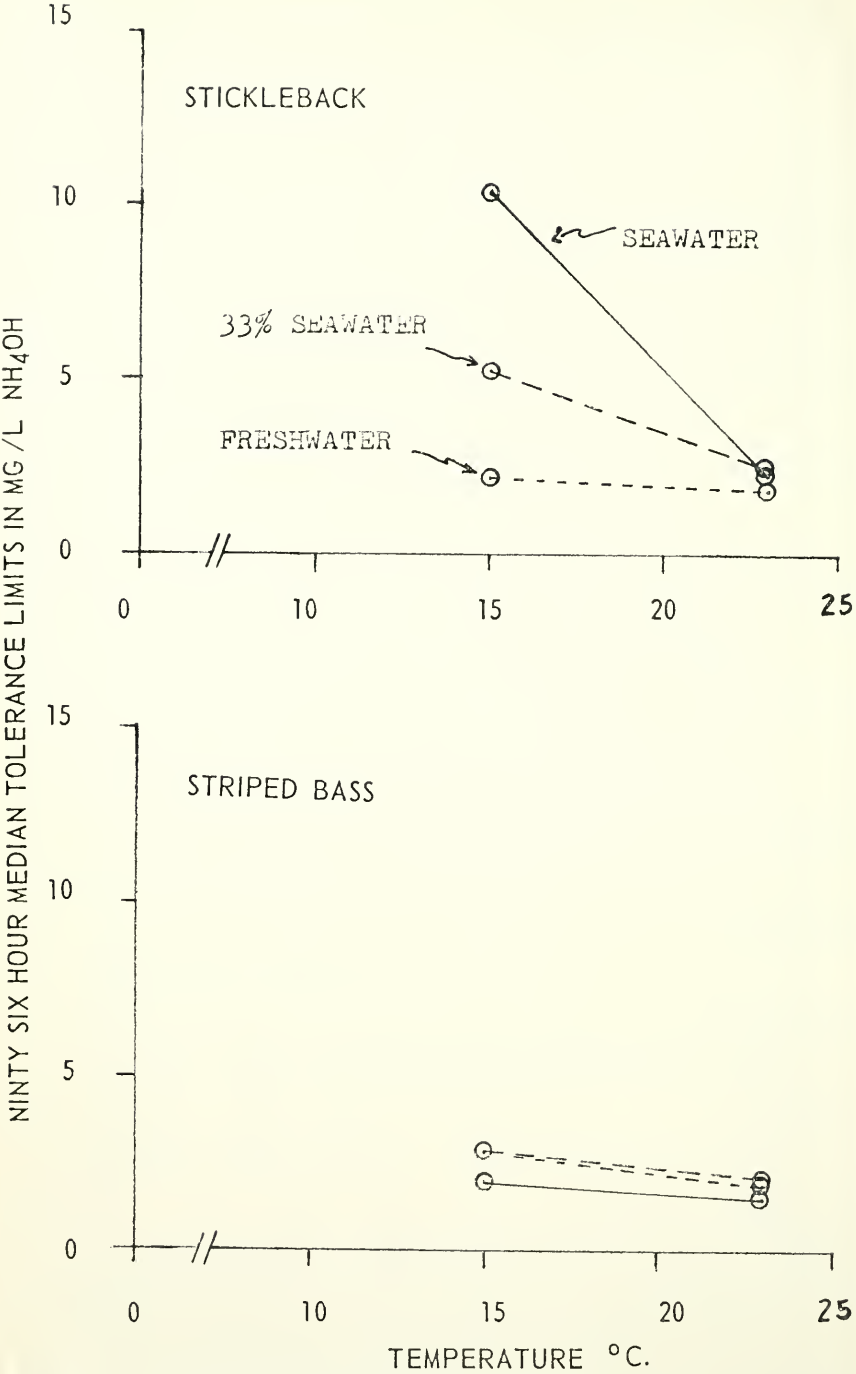

FIGURE 3. The relationship between toxicity and temperature for striped bass and stickleback in freshwater, 33% seawater, and seawater.

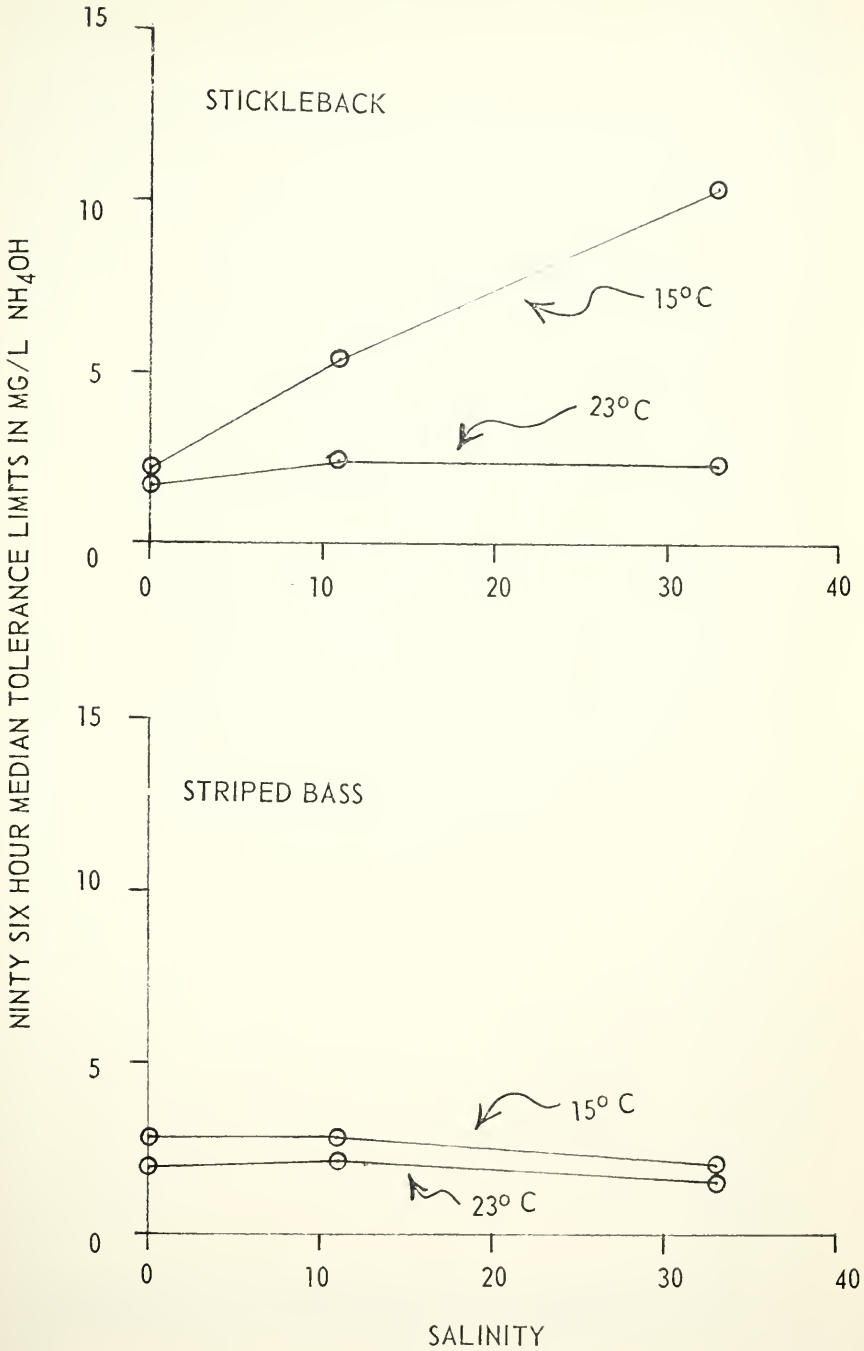

FIGURE 4. The relationship between toxicity and salinity at 15 C and 23 C for striped bass and stickleback.

higher temperature and at higher and lower salinities. Two to five times as much NH_4OH was required to kill sticklebacks as was required to kill striped bass in saline waters at 15 C.

Since a primary excretory waste of the fish is ammonia, an attempt was made to quantify the addition of this metabolite to their 10-liter environment. The amounts of ammonia in the control containers for Bioassays Numbers 49-68 and 50-68 were plotted against time in Figure 5. Over a 96-hr period, the concentrations of ammonia nitrogen increased by about 6 mg liter and 3 mg/liter at 23 and 15 C, respectively. On the basis of the average weight of fish in the test jars, there was an addition of NH_4-N amounting to 0.24 mg/g at 15 C and 0.43 mg/g at 23 C. This difference approximates what may be expected if it is assumed that the metabolic rate doubles with a 10 C increase in

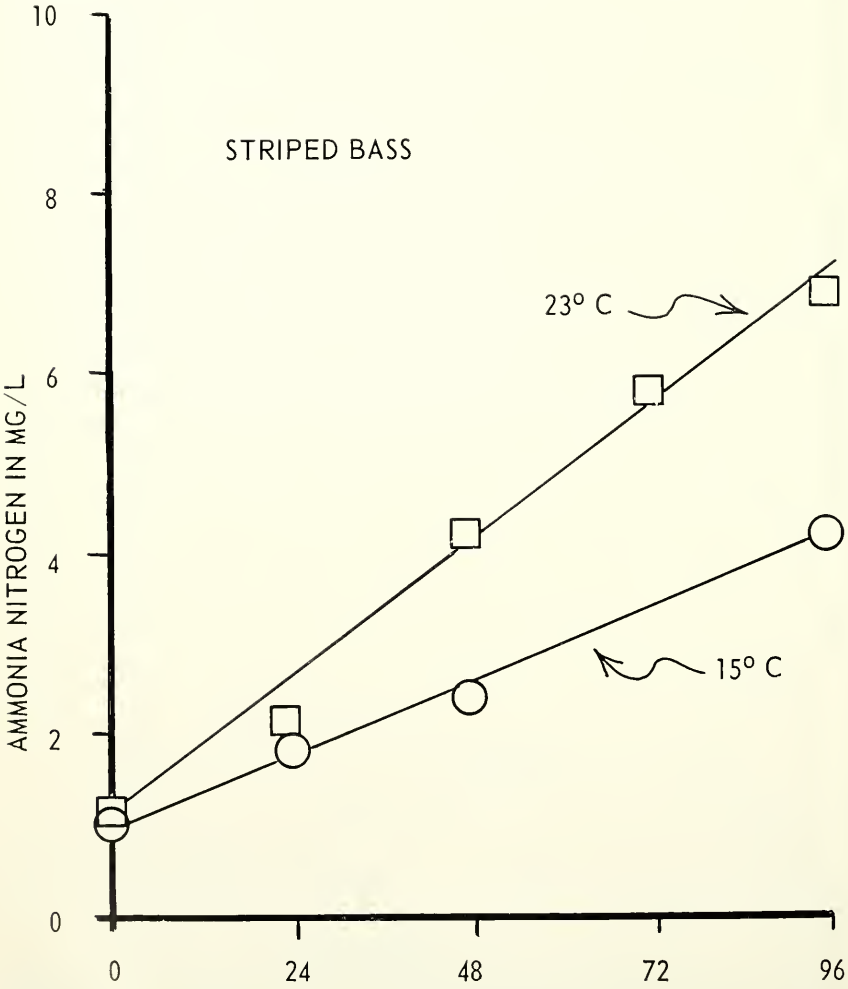

FIGURE 5. Increase of ammonia nitrogen in test containers with time at 15 C and 23 C.

temperature. Increases in ammonia due to metabolism of fish had relatively little significance on the total concentration of ammonia in test containers.

Variation in the total concentration of NH_4-H and pH during a test are major contributors to experimental error. Some idea of the magnitude of this variance can be deduced from information contained in Tables 3 through 8. Standard deviations of measurements of ammonia nitrogen were usually 5 to 20% of the mean in a particular test; however, in some cases they exceeded 50%. Relative variability increased with an increased concentration of ammonia nitrogen. This may be illustrated by use of the coefficient of variation (CV) (Fryer, 1954):

$$CV = \frac{100 \text{ (standard deviation)}}{\text{mean}}$$

Coefficients of variation for ammonia nitrogen in mg/liter are illustrated by the values given below:

Selected Data From Seawater Bioassays

Mean NH_4-N	CV	Mean NH_4-N	CV
11.35	1.76	88	21.79
19.87	1.91	96	29.06
31.70	4.54	134	34.40
51.38	21.43	188	58.03

A progressive analytical error was noticed earlier in the recovery test (Table 1); that is, as concentration increased, accuracy of recovery decreased. The degree of such error has not been determined; consequently, its quantitative effect on the reported results is unknown but is further suggested by the change in coefficient of variation.

Hydrogen ion activity was the other major incompletely controlled variable encountered during these tests. In the seawater bioassays, pH was usually about 8, and during a test the standard deviation of the mean was often between 0.05 and 0.20 units. Such variation in pH can cause significant changes in the quantity of undissociated ammonia present. For example, if the pH of seawater is 8.00 with standard deviation of ± 0.10, the fractional part of the total concentration of ammonia that is undissociated will be between 2 and 3%. In tests with striped bass at pH 8, complete survival was usually achieved at total NH_4-N concentrations of 15 mg/liter or less and 100% kill occurred at concentrations of 75 mg/liter and more. Within the standard deviation of ± 0.10 pH units, the amounts of undissociated ammonia nitrogen present in this example would be 0.30–0.45 and 1.50–2.25 mg/liter, respectively. In ammonium hydroxide equivalents this is 0.75–1.13 and 3.76–5.64 mg/liter. A standard deviation of ± 0.10 pH units under these circumstances was accompanied by a variation of about 50% in the concentration of undissociated ammonia nitrogen.

Because variations in total NH_4-N and pH were major contributors to the wide variation of concentrations of undissociated ammonia that occurred in test containers, knowledge of these variations in such ex-

periments is essential. As reported in the methods section, a series of desired concentrations of NH_4OH were used as a starting base for the tests. During the tests, measurements were made of the total NH_4-N present and from these values we computed the estimated concentrations of NH_4OH actually present. Table 9 is a summary of "expected" values of NH_4OH compared to the averages and ranges of concentrations "observed". The "observed" concentrations averaged higher than the "expected" values. This observation is related to that shown earlier in Table 1. Although errors were found in the assayed values, they are probably more nearly correct than those computed by dilution.

TABLE 9. **Relationship Between the Expected Concentration of NH_4OH in Test Containers to the Observed Concentrations During the Listed Number of Tests.**

	Concentration of NH_4OH in mg/liter		
Expected	Average observed	Range observed	Number tests
0.00	0.17	0.02–0.34	11
0.56	1.07	0.25–2.19	12
1.00	1.56	0.53–3.73	18
1.80	2.68	0.71–7.19	13
3.20	4.48	1.32–10.29	20
5.60	6.64	3.18–11.93	12

DISCUSSION

In our experiments there was little difference in susceptibility to ammonia between striped bass and sticklebacks at 23 C. At this temperature both species showed an increased resistance to poisoning in one-third seawater as opposed to freshwater and seawater. In regard to temperature, striped bass were slightly more resistant at 15 C than they were at 23 C. On the other hand, at 15 C large differences in 96-hr TL*m* values were noted in the case of sticklebacks bioassayed in brackish water and seawater in comparison to freshwater and 23 C tests. In brackish water at 15 C stickleback were about twice as resistant to ammonia as striped bass, and they were 6 times as resistant in seawater.

Such large differences in sensitivity to ammonia poisoning are at variance with results reported for the five species tested by Ball (1967). In his tests, trout were more sensitive than bream, roach, and rudd during the first 48 to 72 hr, but by 96 hr the TL*m* values were approximately the same (0.35–0.41 mg N/liter). From his data one may conclude that many species have similar ultimate limits of tolerance to undissociated ammonia, although there are undoubtedly exceptions such as the stickleback.

Because 96-hr TL*m* or LC_{50} values are often used in setting ammonia waste discharge requirements, knowledge of large differences in sensitivity between species has practical value in the management of waste discharges. For example, an objective of one-tenth the 96-hr TL*m* for ammonia wastes in seawater at 15 C, based on stickleback data, may permit concentrations of undissociated ammonia nitrogen as great as

0.23 mg/liter, which is about one-fourth and not one-tenth the TL*m* value determined under similar conditions for striped bass. Consequently, by this toxicity bioassay application factor, striped bass would not be adequately protected. When the problem is compounded by natural variations in pH and difficulties in assaying ammonia, protection of all fish becomes more uncertain.

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COYOTE MOVEMENTS IN SAGEHEN CREEK BASIN, NORTHEASTERN CALIFORNIA[1]

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A 4-year investigation, 1966 through 1969, of coyote (*Canis latrans*) movements was conducted in the Sagehen Creek area of northeastern California. Trapping was from mid-July to late September. A total of 101 coyotes were trapped, sexed, weighed, and measured. Of 98 which were ear tagged and released there were 26 adult males, 26 adult females, 28 juvenile males, and 18 juvenile females. Recapture or tag return data were from 35 individuals. Coyotes tagged as juveniles accounted for 80% of all recaptures and 46.7% of tag returns. Twenty-six (74.3%) of the recaptures or recoveries occurred within 1 year after release. The average movement recorded for adults was 4 miles for males, 4¾ miles for females, and the juvenile males and females averaged 3¼ and 4 miles, respectively. The longest movement was 87 miles recorded for a juvenile male. This animal was considered a drifter and was not used in the calculations.

The weights of 101 adult coyotes ranged from 18 to 27½ lb. for males (average = 24¼ lb.), and 17 to 26½ lb. for females (average = 21½ lb.).

INTRODUCTION

Relatively few studies on coyote movements have been reported in the literature. Garlough (1940) obtained movement data from 110 coyotes marked and released in Wyoming. The Bureau of Biological Survey initiated coyote tagging programs in New Mexico, Colorado, Montana, and Wyoming (Young and Jackson 1951). Robinson and Cummings (1951) reported on the movements of 178 coyotes tagged in Yellowstone National Park. Additional authors reporting on coyote movements were Nellis and Keith (1967) working in central Alberta, and Clark (1968) working in Utah and Idaho.

This study was conducted to investigate the movements of coyotes in typical habitat along the eastern slope of the Sierra Nevada in northeastern California. The information in this paper was gathered over a 4-year period, 1966–69, in the Sagehen Creek basin and vicinity.

DESCRIPTION OF THE STUDY AREA

This study was conducted in the vicinity of the University of California's Sagehen Creek Field Station (Figure 1) located approximately 8 miles northwest of Truckee, California. The field station and study area are situated along the eastern slope of the Sierra Nevada in the Tahoe National Forest. The area encompassed by the study varied in elevation from approximately 6,300 to 5,000 ft above sea level.

In 1960, the Donner Ridge forest fire burned across the middle of the Sagehen Creek basin and parts of the surrounding study area. This extensive fire denuded much of the area through which it burned.

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[2] The data comprised part of an MS thesis filed with the University of Nevada, Reno, June, 1970.

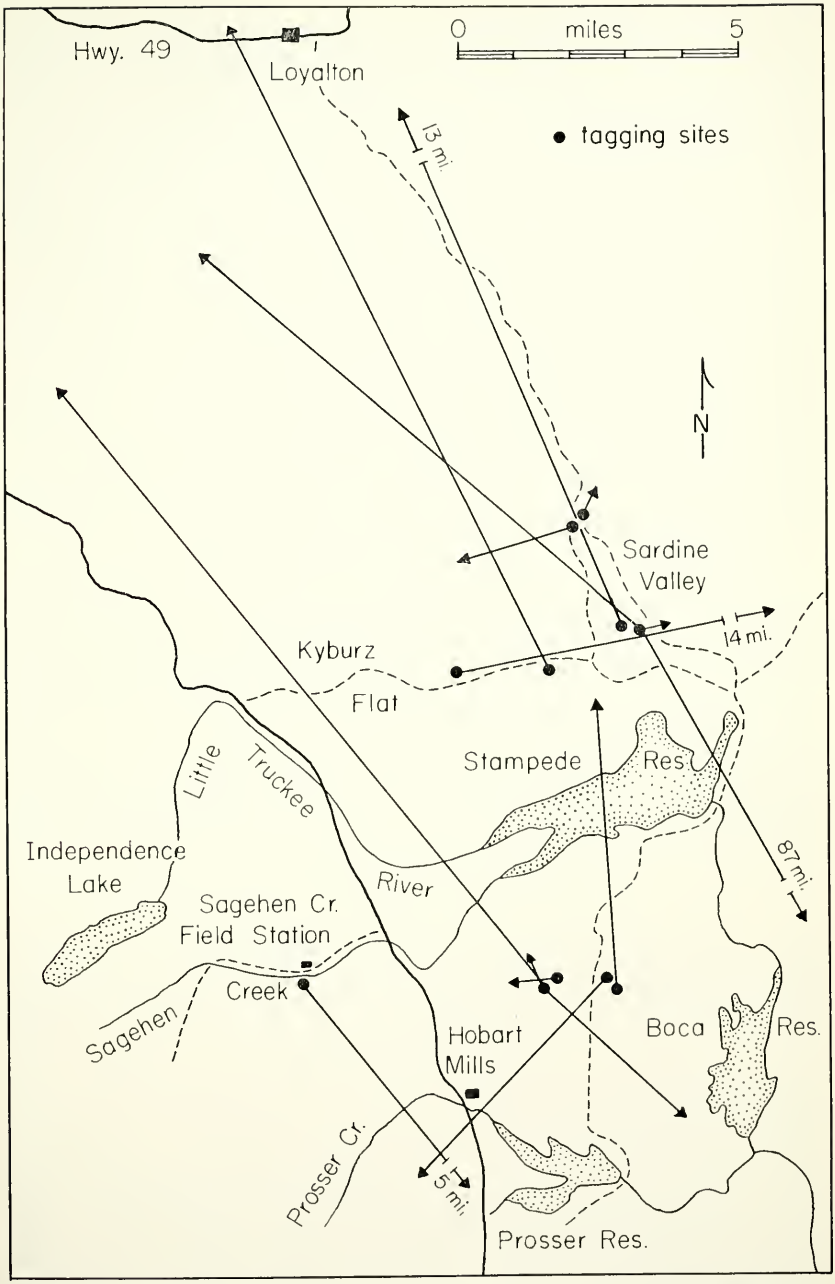

FIGURE 1. Coyote movements based on tag returns. Movements of animals recaptured on the trap line are not shown.

Sparse brush with an overstory of conifers covered much of the study area prior to the fire. The principal conifers found on the unburned parts of the study area today are red fir (*Abies magnifica*), white fir (*Abies concolor*), Jeffrey pine (*Pinus jeffreyi*), yellow pine, (*Pinus ponderosa*), and lodgepole pine (*Pinus murrayana*). The primary understory vegetation on the unburned areas are greenleaf manzanita (*Arctostaphylos patula*), tobacco brush (*Ceanothus velutinus*), rabbitbrush (*Chrysothamnus nauseosus*), squaw currant (*Ribes cereum*), squaw carpet (*Ceanothus prostratus*), and mule ears (*Wyethia mollis*). Antelope brush (*Purshia tridentata*), and sagebrush (*Artemisia tridentata*), cover the more open, drier sites. In the years following the fire, brush species, primarily manzanita and tobacco brush, reinvaded the burn. The U. S. Forest Service seeded the burned area with orchard grass (*Dactylis glomerata*) and Johnson grass (*Sorghum halepense*). Quaking aspen (*Populus tremuloides*), mountain alder (*Alnus tenuifolia*), and four kinds of willow (*Salix* spp.), are found along the streams and in some of the moist meadows.

The Sagehen Creek basin and much of the study area was logged in the late 1800's and early 1900's. The second growth timber is now of sawlog size. Scattered logging operations were conducted in parts of the study area during the 4 years of this investigation.

The climate is characterized by long, cold winters and warm, dry summers. Most of the annual precipitation falls in the form of snow. More than half the total precipitation falls in January, February, and March with less than 3% in summer (Storer and Usinger 1964). Weather data recorded at the Sagehen Creek Field Station show an average winter snow pack of approximately 44 inches, but in the exceptionally severe winter of 1968–69 a record pack of 134 inches was recorded. Snow remains at the field station from about the first of November to the middle of April. The snow pack toward the lower, eastern part of the study area (Figure 1) is not as deep in the winter nor does it remain as late in the spring as at the field station.

METHODS AND MATERIALS

In consultation with federal trappers of the Wildlife Services Division, a trap line 51 miles long was established within the study area. "Victor Special" No. 3, offset jaws, double-spring traps were used. Each trap was secured to a stake by a chain. The number of traps set each year varied from 36 to 46. The traps, with a few exceptions, were reset at the same sites each year. After the first year, additional traps were added to the line and a few traps were relocated in areas where coyote activity was more apparent.

Traps were set within the study area along trails or at locations that seemed most likely to be visited by coyotes. The trapping effort was initiated each year during the third week of July when it was anticipated pups born in the spring would be traveling with the adults and would be available for capture. The traps were removed during the third week in September, just prior to the beginning of the local deer hunting season.

Each set consisted of one trap. Both the "open set," and the "hole set" (Hall 1946) were used. Sets which caught animals were reset and

rebaited. On several occasions sets that caught badgers were so badly dug up that the traps were relocated several feet from the original sites. No pattern was established for the two different types of settings.

Several methods were tried to prevent damage to the coyotes' feet. The trap jaws were padded with two tight layers of burlap wrapped over the trap jaws. A shock absorber of a 12 x 2-inch piece of inner tube was fastened to a 2-ft trap chain. In addition, tranquilizer tabs (Balser 1965) were attached to the trap jaws. The most successful methods used were padded trap jaws and the 2-ft trap chain. When this combination was employed visible foot damage was negligible.

All coyotes released during 1966 were ear-tagged with one "sheep size," self-piercing aluminum ear tag (Salt Lake Stamp Co., Salt Lake City, Utah). During 1967 a tag was placed in each ear. An identification number appeared on one side of the tag and a return address on the other side. In addition to ear tags, a spring bronze collar was attached to all adult coyotes released during 1968 and 1969. The collars were made from stock supplied by The American Brass and Copper Company, Emeryville, California. Several holes were drilled in each end of the collar so that the collar could be adjusted to the neck size of the individual coyote. The collars were attached with two rivets. Inscribed on the collar was a return address, an identification number, and notice of a reward of $2.00 for return of the collar and $3.00 for return of the carcass.

All coyotes were weighed, measured, sexed, and a statement on condition was recorded. Coyotes known to be born during the year in which they were trapped were classified as juveniles and all others as adults.

RESULTS

During the 4 year program the traps were set for 257 days for a total of 9,670 trap-nights. The trapping effort resulted in an average of 1.04 coyotes captured for each 100 trap-nights. A total of 101 coyotes was trapped which included 28 adult males, 26 adult females, 28 juvenile males, and 19 juvenile females. One coyote died and two were killed in the trap.

Weights

The weights ranged from 18 to 27½, and 17 to 26½ lb. with an average of 24½ and 21½ lb. for adult males and females, respectively. The weight range for juvenile males and females was 7 to 22 lb.

Recaptures and Tag Returns

Of the 98 coyotes marked and released during this investigation, tag return or recapture data were accumulated on 35. Twenty of the tagged coyotes were recaptured. I retrapped and released 12 coyotes. A government trapper working within the study area trapped and killed eight of the tagged animals. Since these animals were trapped they will be treated as recaptures rather than tag returns. Males and females were retrapped in equal proportion. Eight male and eight female coyotes tagged as juveniles were recaptured. Of these, eight were recaptured during the summer they were tagged, seven the following summer, and one the second summer after tagging. Three of the four recaptured

adults were taken during the summer they were tagged, and one was taken the second summer after tagging. In all, 18 of the 20 recaptures (90%) occurred within a year after initial marking.

Only one coyote was captured three times. A 12½ lb. female pup was retrapped 1 day after release, ½ mile from the release site. She was retrapped and killed, 13 days later, 1 mile from that release site.

In addition to recaptures, tag returns were obtained from 11 male and four female coyotes. Hunters accounted for 12 returns, two were road kills and one was found dead. Tags returned within 1 year after release, from the four animals tagged as juveniles, accounted for 26.7% of the total returns as compared to 80% for recaptures. Eight (53.3%) of the recoveries occurred within 1 year after release. Of all recaptured or recovered coyotes 26 (74.3%) were taken within 1 year after release.

Movement Data

From Recaptures. Movements were plotted to the nearest ¼ mile on a U.S. Geological Survey (15 minute series) topographic map. Fourteen (70%) of the animals were recaptured within 2 miles of the release site.

The two males and two females tagged as adults averaged 1¾ and 2 miles, respectively, between the release and recapture sites. The range was from 0 (recaptured in the same trap) to 5¼ miles for males and ¾ to 2¼ miles for females (Table 1).

For the coyotes tagged as juveniles, the eight males averaged 2 miles between release and recapture sites whereas the eight females averaged 1½ miles. The range was from 1/10 to 5¼ miles for males and ½ to 4¾ miles

TABLE 1. Movements in Miles of 34 Coyotes

	Average	Range
Recaptures		
Adults*		
(2) Males	1¼	0 – 5¼
(2) Females	2	¾– 2¼
Juveniles†		
(8) Males	2	1/10– 5¼
(8) Females	1½	½– 4¾
Tag returns		
Adult		
(6) Males	5¼	½–13
(2) Females	2¼	3½– 5
Juveniles		
(4) Males	5½	½–14½
(2) Females	13¾	13½–14
Recaptures and tag returns		
Adults		
(8) Males	4	0 –13
(4) Females	4¾	1¾– 5¼
Juveniles		
(12) Males	3¼	1/10–14½
(10) Females	4	1/10–14

* Returns to animals tagged as adults.
† Returns to animals tagged as juveniles.

for females. A male, tagged as a juvenile, was recaptured 711 days after release $\frac{1}{10}$ of a mile from the point of release.

From Tag Returns. Individuals who sent in tags from dead coyotes were mailed a topographic map and asked to indicate on the map the location in which the coyote was killed. The data gathered from tag returns show a somewhat greater movement pattern than the recapture data (Table 1). A male, tagged as a juvenile, was killed along a highway 87 miles from the release site. Since none of the other coyotes were recovered more than 15 miles from the point of release, this animal was considered a drifter and was not figured into the average movements of the other 14 coyotes.

DISCUSSION

Weights

Young and Jackson (1951) listed the coyotes' weight between 18 and 30 lb., with a record weight of $74\frac{3}{4}$ lb. for a male. Gier (1968) found an average weight of 30.7 lb. for adult males and 26.0 lb. for adult females. The weights ranged from 18 to 43 lb. The adult male and female coyotes in the Sagehen Creek basin averaged $6\frac{1}{2}$, and $4\frac{1}{2}$ lb. less, respectively, than those reported by Gier (1968) for Kansas coyotes. Also, the heaviest coyote in this study weighed $15\frac{1}{2}$ lb. less than the maximum weight recorded by Gier.

Recaptures and Tag Returns

Combining the recapture and tag return data, information was accumulated for 35 (35.7%) of the 98 coyotes marked and released. In Wyoming 48.1% of 110 tagged coyotes were recovered (Garlough 1940). Robinson and Cummings (1951) reported a recovery rate of 41.5% of their 419 marked coyotes. In Garlough's study the coyotes were tagged and released in an area in which extensive predator control was being conducted. Likewise, Robinson and Cummings made a special effort to collect their marked animals. Each tagged coyote had the tip of one ear cropped. At a later date coyotes with cropped ears were sought out and shot. The circumstances of both these studies tended to insure a relatively high rate of return.

Of the 26 coyotes of each sex that I tagged as adults, only two males and two females (7.7%) were retrapped. Coyotes tagged as juveniles made up a high proportion of the recaptures, since 34.8%, eight males and eight females, of the 46 juveniles released were recaptured. Animals tagged as juveniles made up 80% of all recaptures; hence it appears that inexperienced juveniles are more susceptible to retrapping than the adults.

Data received from tag returns presents a slightly different picture. This information shows 15.3% of the tagged adults and 15.2% of the animals tagged as juveniles were recovered. Why a smaller percentage of tag returns, as compared to recaptures, was obtained from juveniles is not clear. Robinson and Cummings (1951) also found a lower rate of recovery was obtained from coyotes tagged as juveniles. Presumably many juveniles are lost from the population before they can be recovered.

Movements

All of the 20 recaptures in this study occurred within 5¼ miles of the release site. This suggests that at least during the summer period of trapping, the coyotes in this area are a resident population with limited movement.

The data from tag returns (Figure 1) for the 14 coyotes shows a slightly more extensive range of movement than does the recapture data. However, the average distance of 6½ miles between release and recapture sites in this study is well below the averages of 26 and 28 miles reported, respectively, by Garlough (1940) and Robinson and Cummings (1951).

Garlough (1940) reported male coyotes averaged 3 miles more than females in average movements. Robinson and Cummings (1951) found coyotes tagged as juveniles averaged 7.4 miles more than adults, and females averaged 2 miles more than males between release and recovery sites

Combined tag return and recapture data in this study reveals that the differences in average movements between males and females and between coyotes tagged as adults and as juveniles did not exceed ¾ of a mile. These differences were not significant.

While the average movements calculated from return and recovery data would indicate a population of coyotes with a rather limited movement pattern, this may not necessarily reveal the year-round situation. The five coyotes that were recovered at a distance greater than 10 miles from the release site were all taken during the late autumn or winter. In addition, the drifter was recovered during the winter after having been recaptured near the release site the summer following release. Four of the animals moved in a northerly direction into Sierra Valley which receives light winter snowfall. A fifth coyote moved in an easterly direction, also into an area with light winter snowfall. The immediate study area is a region of heavy snowfall which may accumulate a snow pack of 6 ft or more. The number of tag returns is too small to be conclusive, but the data suggest that some of the coyotes do move out of the study area during the winter. McLean (1934) and Robinson and Cummings (1951) reported movement of coyotes out of the mountains during the winter and a return movement during the spring. Some coyotes remain in the Sagehen basin over winter, but the proportion of the whole population that does so is not known.

ACKNOWLEDGMENTS

I wish to thank Dr. A. Starker Leopold, whose encouragement and advice made the study possible. The writer is indebted to many people from the U.S. Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services, whose interest and advice greatly enhanced the success of the study, especially Malcolm N. Allison, Ronald Thompson, and Richard A. Wonacott. Drs. Ronald L. Church, and Michael J. Pontrelli of the University of Nevada, and Marshall White of the University of California offered helpful suggestions concerning both the study and the manuscript.

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Calif. Fish and Game 57(3) : 138–153, 1971.

CALIFORNIA DEER DEATHS DUE TO MASSIVE INFESTATION BY THE LOUSE (*LINOGNATHUS AFRICANUS*)[1]

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Wildlife Management Branch
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In December 1967 34 deer died on the Tejon Ranch in Kern County, California. A fawn was submitted to the Wildlife Investigations Laboratory to ascertain cause of death. No evidence of infectious disease was found. The animal's death was due to exsanguination anemia which resulted from infestation by tremendous numbers of the African blue louse (*Linognathus africanus*, Kellogg and Paine). Four other occurrences of this louse in different California deer herds have been found.

INTRODUCTION

Anemia associated with heavy infestations of ectoparasites has been reported in animals. Fenstermacher and Jellison (1933) reported severe anemia in moose caused by the tick, *Dermacentor albipictus*. Anemia in sheep and jackrabbits due to *Dermacentor andersoni* was found by Philip, Jellison and Wilkins (1935). Anemia associated with lice is not common. Peterson, et al. (1953) reported anemia in cattle caused by the cattle louse *Haematopinus eurysternus*.

Two species of lice are commonly found on deer in California, the blood sucking louse *Solenopotes ferrisi* and the biting louse *Trichodectes tibialis*. *S. ferrisi* has never been found in high numbers and apparent ill effects from this parasite have not been observed. *T. tibialis* has been found occasionally in high numbers but other than irritation to the host, no other effects have been observed.

The type species *L. africanus* was recorded from sheep in southern Nigeria, Africa. It was later recorded from domestic sheep and goats from various localities in Africa, India, southern United States, Puerto Rico and Hawaii (Ferris, 1951 : Babcock and Cushing, 1942).

No previous records of the African blue louse on deer in the United States are known. This paper reports not only the occurrence of this ectoparasite on two new hosts (i) California mule deer (*Odocoileus hemionus californicus*), and (ii) Columbian black-tailed deer (*O. h. columbianus*), but deer deaths caused by massive infestation of the African blue louse.

MATERIALS AND METHODS

In December 1967 losses of deer occurred on the Tejon Ranch in Kern County, California. The terrain involved is steep hillside from about 2,000 to 4,000 ft in elevation and is mostly open oak-grassland with intrusions of southern California chaparral and coastal type plants (Figure 1). Thirty-four carcasses of California mule deer were found,

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primarily fawns, as well as adults of both sexes. Losses seemed to be localized in an area of 2 square miles and affected animals were in canyon bottoms and flats in areas where deer concentrations were highest. Two fawns in a weakened condition were caught and both died shortly thereafter. One of these animals was shipped immediately to the Department of Fish and Game Wildlife Investigations Laboratory in Sacramento.

The entire skin was excised from the fawn. Hair was removed by boiling the skin in 15% NaOH. The suspended materials and solutions were washed through a 60 mesh screen. A complete necropsy was performed on the carcass.

FIGURE 1. Typical terrain of the Tejon Ranch, Kern County where infestation of the African blue louse on deer was discovered. *Photograph by H. Cribbs.*

RESULTS

The fawn had a massive infestation of a species of louse identified as *Linognathus africanus* (Kellogg and Paine), commonly called the African blue louse. The lice were distributed over the entire body surface. The white haired parts of the skin appeared black due to the enormous numbers of parasites and eggs attached to the hairs. On autopsy the tissues were pale and bloodless. No evidence of infectious disease was found. Cause of death was exsanguination anemia caused by the tremendous numbers of this blood sucking louse.

The lice separated by the NaOH treatment were washed into a 1 liter graduate, and after settling they occupied a volume of 600 ml. It was estimated that this 35 lb. fawn had a burden of 1½ to 2 million lice.

Subsequent examination of deer carcasses in the field showed that all had massive parasitism. No infectious diseases were involved in these losses. Affected animals were emaciated (Figure 2).

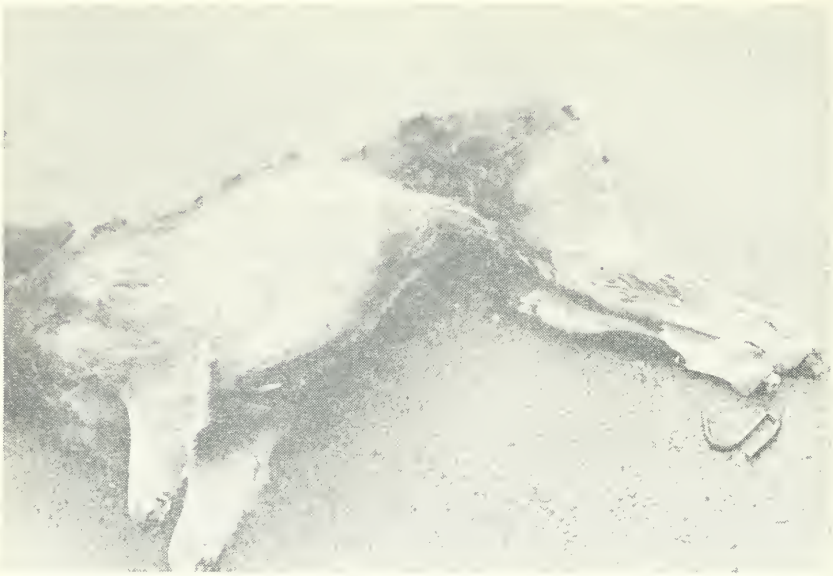

FIGURE 2. A deer carcass showing extreme emaciation resulting from massive infestation by the African blue louse. *Photograph by William Castle.*

DISCUSSION

This louse ordinarily spends its entire life on its host. The nits or eggs are attached to the hairs and hatch in 7–14 days. From egg to maturity may take from 14–75 days.

Subsequent studies on the Tejon Ranch have shown that as is the case with most lice, the increase and decline of *L. africanus* are subject to weather conditions. There was a gradual increase in louse numbers by fall with maximum numbers noted in late winter and early spring. As air temperatures increased infestation declined until high summer temperatures were reached when it became difficult to find the parasite on deer. As a result of this cycle, parasitized animals would be in a weakened condition at that time of year when stress due to storms, snow and cold would be highest. During the course of the study on the Tejon Ranch, it was found that losses occurred during December and January, particularly during times of heavy snowfall. Examination of carcasses of deer at this time showed that nearly all were heavily parasitized by this louse and probably did not have the stamina to withstand the effect of weather. Simultaneously deer in the same area which were collected for study and found free of lice showed no effect from stress due to weather.

Since the first finding of *L. africanus* on deer in Kern County, four other occurrences on deer have been established in California (Figure 3). These were (i) Hunter Liggett military reservation in Monterey County, (ii) the Parkfield area of Monterey County, (iii) Murrieta Canyon in Ventura County, and (iv) near Winters in Yolo County.

Food habit studies were performed in 1968 on the stomach of a European boar (*Sus scrofa*) which had been shot on Hunter Liggett military reservation in April 1965. The pig had eaten portions of a deer and *L. africanus* was found among the stomach contents.

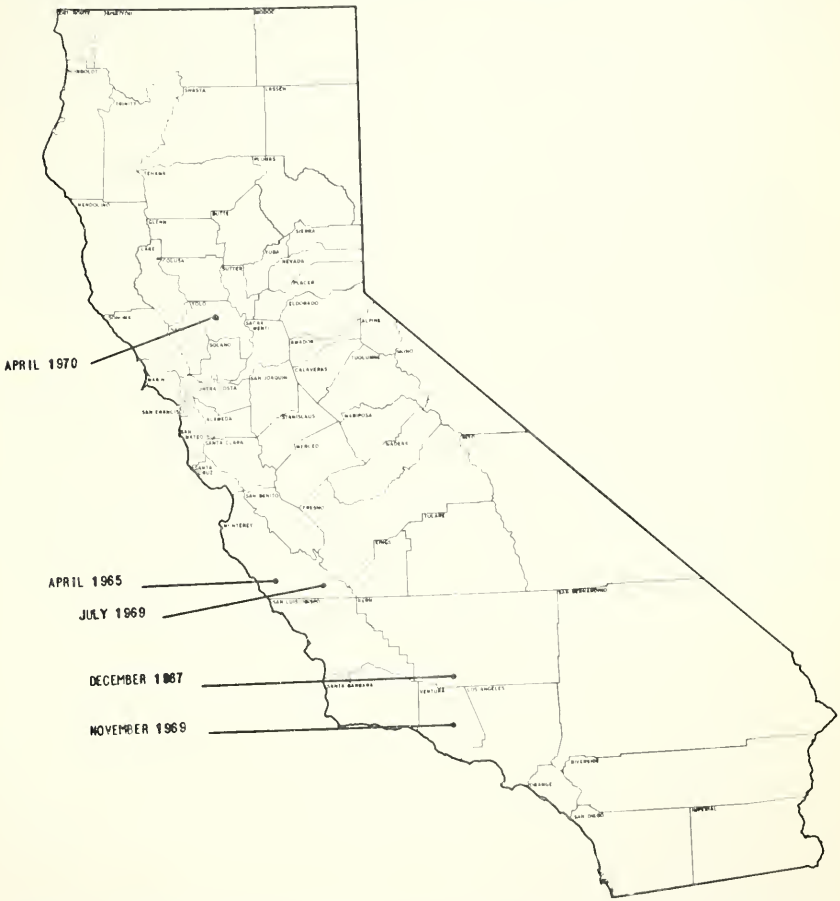

FIGURE 3. Outline map of California showing currently known localities of infestation of deer by the African blue louse.

A fawn died in 1969 in the Parkfield area. Examination of the animal revealed that it had succumbed to a massive infestation by African blue lice. Eighteen dead deer were found in Murrieta Canyon in 1969 and *L. africanus* was the cause of death. Near Winters, a doe which had died of other causes in 1970 was host to a light infestation by the same ectoparasite.

All occurrences of *L. africanus* were on black-tailed deer with the exception of those in Kern and Ventura counties which had California mule deer as the hosts.

These findings would indicate that the original discovery was not an isolated instance of a new introduction into the area, but that the parasite has been present on deer in California in various locations and had not been found previously. Department of Agriculture records show that the louse had been found previously on sheep in California (Ralph Annereaux, pers. comm.). *L. africanus* is one of the more important parasites of goats in the United States but seems to be restricted mostly to the southern part of the United States. It now appears that this louse infested the Tejon deer herd in the past and may have been a factor in previous die-offs on this ranch.

ACKNOWLEDGMENTS

Appreciation is expressed to the Tejon Ranch for their cooperation in this study, and especially to Walter Fieguth of this ranch. We are indebted to Louis Wakefield of the Department of Parks and Recreation and to the Department of Fish and Game personnel who assisted in this study.

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Calif. Fish and Game 57(3) : 167–176. 1971.

SEQUENTIAL MORTALITY OF THE FISH FAUNA IMPOUNDED IN CONSTRUCTION OF A MARINA AT DANA POINT, CALIFORNIA[1]

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Environmental parameters such as dissolved oxygen, water temperature, and salinity were monitored in a drawn-down impoundment at Dana Point, California, during July and August, 1969. Sequential mortality of marine fishes occurred in this impoundment. The first major peak of mortality corresponded to a 2 to 5 ppm decrease in oxygen and a temperature increase of 8 to 9 C. The other two peaks corresponded to temperature peaks 10 to 12 C above ocean temperatures. Surfperch (Embiotocidae) seemed to be least tolerant of environmenal stresses encountered, while elasmobranchs and flatfishes were the most tolerant.

INTRODUCTION

The relationship of parameters such as water temperature and oxygen concentration to mortality of aquatic organisms is extremely important in studies of organic and thermal water pollution. Municipal and state agencies are often faced with the problem of establishing limits on minimum oxygen levels in estuaries, rivers, and harbors subject to organic pollution and limits on maximum water temperatures of warm water effluents. Many times there is not adequate information available concerning affects of these factors on aquatic organisms living in the area. This study provides mortality data for a number of southern California marine fishes with respect to dissolved oxygen concentration and water temperature under relatively natural conditions.

Tolerance limits of some fishes to various environmental stresses have been examined (Raffy, 1952; Muzinic, 1964; Hubbs, 1964; and Heinicke and Houston, 1965). Most studies have been performed in the laboratory, enabling rather precise manipulation of various environmental parameters but generally limiting the number of species examined. Field studies of fish mortality have been made after mortality occurred, with environmental measurements not taken concurrently with the observed mortality (Barlow, 1958; Geagan, 1960; Rae, Johnston, and Adams, 1965; exceptions are Carpelan, 1961; Bailey, 1955; and Krishnamoorthy and Visweswara, 1963). Normally, it is difficult to predict when and where mass mortality will occur thus making adequate measurement of important parameters virtually impossible. Our study includes continuous monitoring of such parameters prior to and concomitant with a survey of fish mortality in a marine habitat artificially isolated from the Pacific Ocean.

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LOCALITY AND DESCRIPTION OF STUDY AREA

The construction of a large marina at Dana Point, California, necessitated diking off several intertidal and subtidal areas and then pumping the water out prior to land fill operations. The location of the project is just south of Dana Point. In this area, the beach is protected by a rock jetty $\frac{1}{4}$ mile offshore. Impoundment and pumping operations were started in May 1969. Three areas were sequentially impounded: one of approximately 10 acres, and two of 40 acres each. Since we did not learn of the project until June 1969, we were able to study only the third impoundment.

The study area was diked off on approximately June 15; pumping was initiated on June 21, continued without interruption for about 2 weeks, and intermittantly thereafter. The location of the pumps prevented a draw down greater than 12 ft, and seepage through the dike walls necessitated running the pumps for a few hours each week after July 1, 1969. The original maximum water depth in the impoundment was 19 ft; average depth was 12 ft. Pumping reduced the main water area from about 40 acres to about 6 acres along the seaward dike. Maximum water depth after pumping was 7 ft.

In addition to the main pool, the draw down produced a small pool (150x50 ft) about 3 ft deep, landward of the main pool. Many fish from the shallower area of the impoundment were trapped in this pool; all others were in the main pool.

Construction was halted on July 19 for 4 weeks due to a strike of heavy equipment operators. Pumps were run briefly every 10 days or so to keep the water level constant—the level fluctuated about $2\frac{1}{2}$ ft during this period.

PROCEDURES AND TECHNIQUES

The main pool was monitored for mortalities and water conditions continuously from July 3 through July 18; after July 18, measurements were made twice a week until September 5, at which time the study terminated. From July 3 to 18, temperature, dissolved oxygen concentration, and salinity for surface and bottom waters were measured at 4 hr intervals from 0630 to 2230 daily. Fish mortality surveys were made twice a day during this period. After July 18, measurements were taken every 3 or 4 days at 1030 and 1430 and one mortality survey was made at 1200.

Temperatures were measured with a Yellow Springs Instruments telethermometer (Model No. 42SC, Probe No. 402) enabling us to make direct surface and bottom readings.

Oxygen concentration was measured in three ways. From July 3 to 29, oxygen concentrations were determined using the unmodified Winkler technique (Welsh, 1948). A modified Winkler technique was used from July 2 to August 11, and from August 14 to September 5, a Beckman Oxygen Analyzer (Model No. 777) was used. The changes in method of oxygen determination were necessitated by increased water turbidity as our study progressed.

Salinity was measured with a refractometer (American Optical Model TS-A) which measured total dissolved solids. Simultaneous chloride analysis (Aminco-Cotlove titrator) with subsequent salinity calculation indicated refractometer values were ±1% of the chloride titration method.

Fish surveys were made by walking the pool's perimeter and collecting dead fish on the banks. A strong breeze (10 to 20 knots) generally blew for several hours each day and dead fish usually were blown on shore, with the possible exception of some flatfishes. In addition, seinings were made each week to collect sargo *(Anisotremus davidsoni)* for another study. Qualitative observations were thus made on live species throughout the 2 month period.

RESULTS

Temperature

Surface and bottom temperatures in the main pool exhibited daily fluctuations of 3 to 5 C (Figure 1). The pattern of fluctuation was caused by early morning coastal clouds which obscured the sun until approximately noon nearly every day. A stiff breeze generally occurred in the afternoon; the wind promoted mixing of surface and bottom water and probably kept the water temperature down. Highest temperatures for both surface and bottom usually occurred at 1430. Surface temperatures were 0 to 2 C above bottom temperatures; differences greater than 1 C occurred mainly at 1430 and 1830.

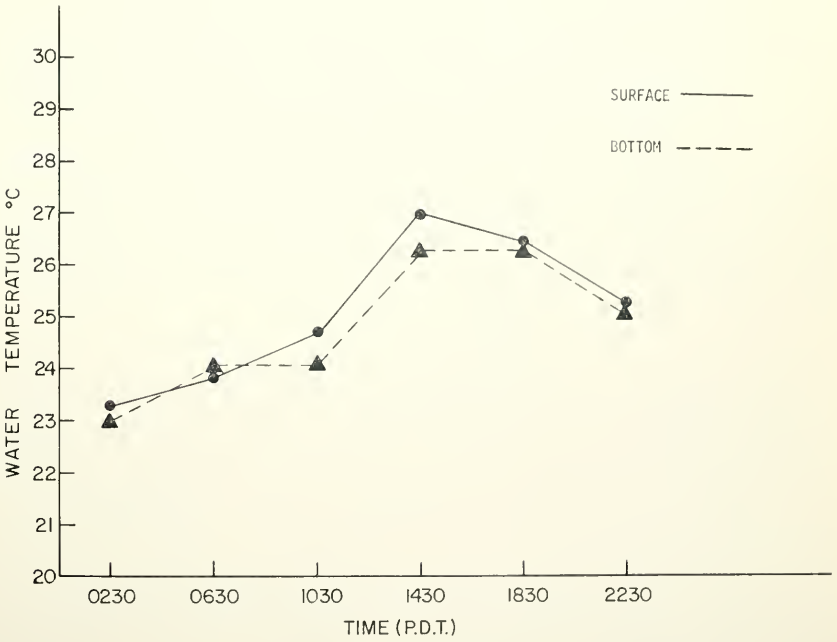

FIGURE 1. Average daily temperature fluctuations in the main pool (July 3 to 18, 1969).

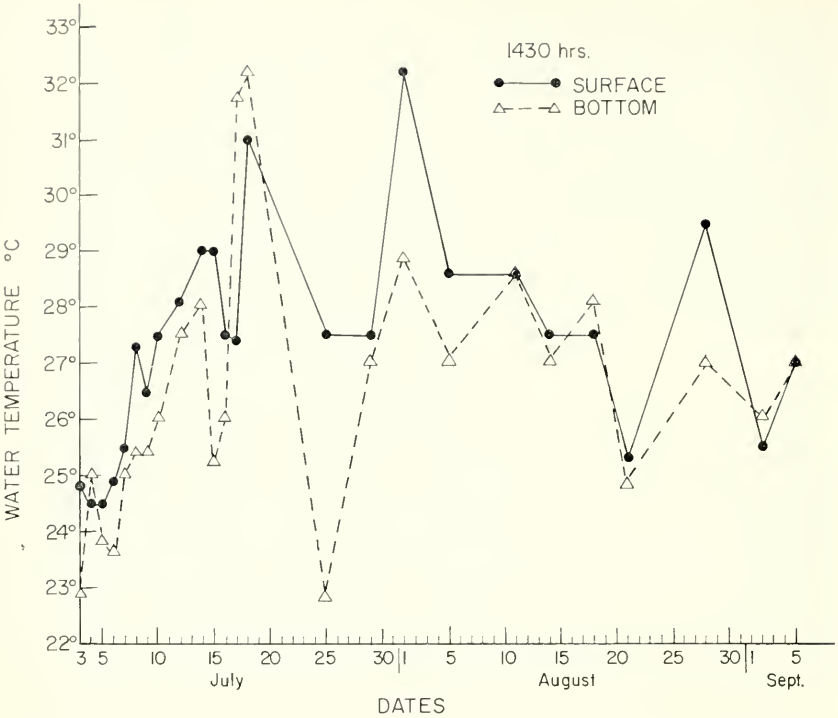

FIGURE 2. Surface and bottom temperatures at 1430 hours during the study. These temperatures also were the daily maximums except for the bottom temperature on July 15 and 16, and the surface temperature on July 17, which were 1.2, 0.5 and 0.7 C respectively below the readings taken at 1830 hours.

There was a progressive warming of the pool from ocean water (19 to 22 C) to a maximum bottom temperature of 32 C on July 18 and on August 1 (Figure 2). This warming presumably began on or shortly after June 15; therefore, water temperatures were already 2 to 3 C above ocean temperatures when our study began. Air temperatures during the study ranged from 20 to 30 C.

Oxygen Concentration

Dissolved oxygen concentrations exhibited daily fluctuations (Figure 3) with lower values normally measured at 0630; the higher readings usually occurred at 1830, but occasionally at 1430. Minimum oxygen concentrations occurred on July 5, (2.5 ppm) and again on July 13 to 15 (2.7 to 2.9 ppm.) (Figure 4). Generally, surface and bottom oxygen concentration readings differed by 0.5 ppm or less. Differences of over 1.0 ppm often were observed in the afternoon (at 1430), presumably when photosynthesis in the surface layer was at a maximum. A progressively increasing algae bloom was evident during the latter half of the study, resulting in supersaturated conditions at both surface and bottom. After July 18, oxygen values generally remained above 5.0 ppm.

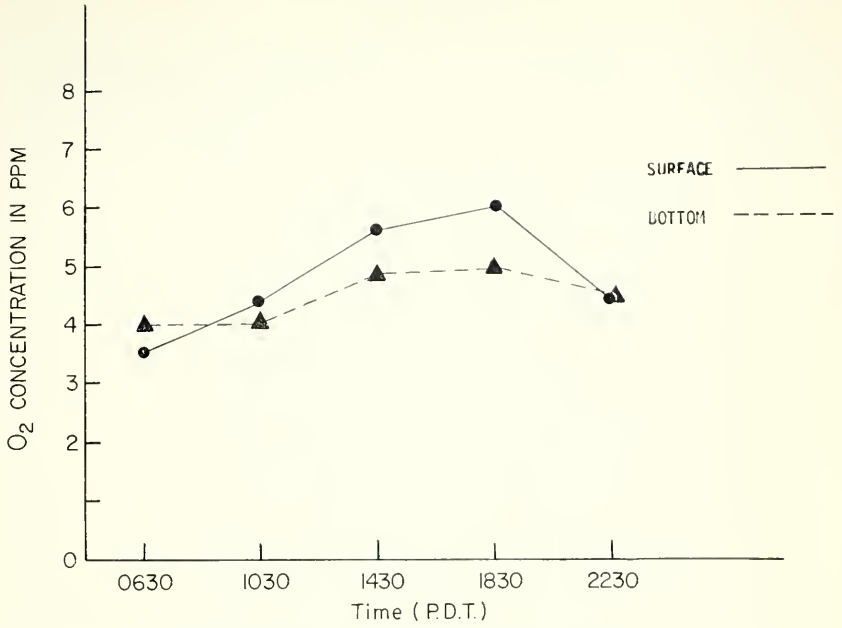

FIGURE 3. Fluctuations in dissolved oxygen concentration on a typical day in the impoundment (July 8, 1969).

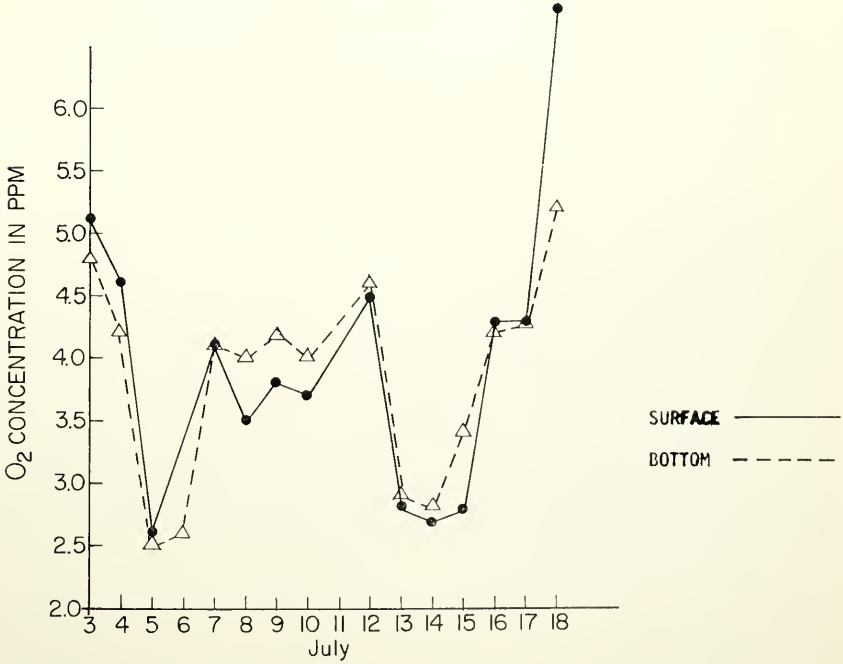

FIGURE 4. Daily minimum oxygen concentrations in the impoundment July 3 to 18. Minimums after July 18 were generally above 5.0 ppm due to an algal bloom.

Salinity and pH

Surface salinity measurements indicated a gradual increase in salinity from 34‰ on July 4 to 44‰ on September 5 Table 1). Measurements of pH were made only near the end of the study and these indicated that from August 18 to September 5, pH remained between 8.1 and 8.4.

TABLE 1. **Weekly Changes in Salinity.***

Date	Salinity (‰)
July 4	34.0
11	35.5
18	37.0
25	40.0
August 1	40.0
8	40.8
14	42.0
21	42.5
28	43.0
September 5	44.0

* Measurements were taken at 1030 PDT daily from July 3 to 18, and at 3 to 4 day intervals thereafter.

Fish Mortality

We found 44 species of fish in the Dana Point impoundment (Table 2). We estimated at least 19 species suffered total mortality during the study. Approximately 83% of main pool mortalities (and 90% of small pool mortalities) occurred during the period July 12 to 20 (Figure 5). By July 29, all fish in the small pool had died.

If a species in the main pool exhibited mortality during the early part of the study, followed by a period of no recorded mortality, and was not caught in any of the seinings made in August, it was assumed that this species had completely died off. The dates of 50% and 95% mortality were then estimated for such a species. We have ranked the hardiness of fish according to the estimated date of 95% mortality (Table 3). When dates were identical for several species, the date of 50% mortality was also considered. Species considered least hardy are listed in group 1, while those showing increased tolerance were placed in group 2. Of the 44 species reported, 26 were counted in sufficient numbers to estimate relative hardiness.

During the latter half of August, mortalities dropped to practically nil. On approximately September 1 construction crews began filling the main pool with dirt. The most numerous fish remaining in the pool at this time were round stingrays, California halibut, kelp bass, sand bass, spotted sand bass and sargo.

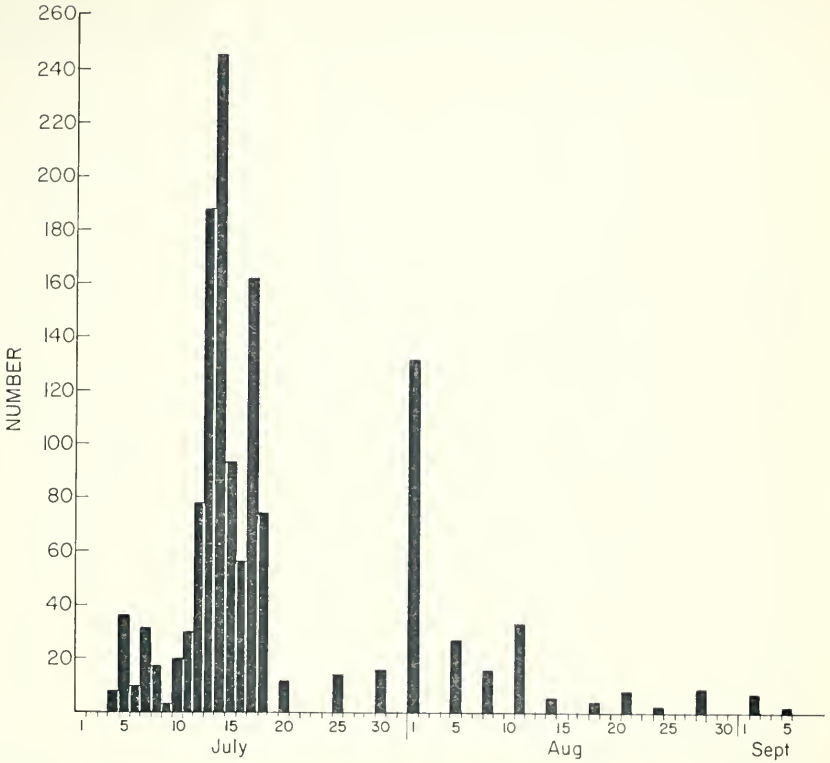

FIGURE 5. Fish mortalities (all species) in the main pool during the study.

DISCUSSION

Mortality data can be examined in the light of temperature and oxygen measurements. Combined main pool mortality for all species was 1,335 deaths, 82% (1,097) of which occurred between July 12 and July 18 (Figure 5). Mortality rates peaked on July 13, 14, 17 and August 1. The increased number of deaths on July 13 and 14 correlates with a drop in the minimum oxygen concentration, and reflects deaths of large numbers of small barracuda (11–12 inches), black perch, and others. Low oxygen concentrations were 2.7 to 2.9 ppm, and combined with the moderately high temperature (28–29 C) probably were the major causes of the mortality peaks on July 13 and 14. The July 17 peak coincided with a large increase in maximum bottom temperature which reached 31.7 C. The August 1 kill, although representing a 3 day period, corresponds to the second major temperature peak (Figure 2) of 32.2 C for surface water (28.9 C for bottom water). Since ocean temperatures were between 19.5 and 22.0 C before and during this study, peak temperatures were 9 to 12 C above normal and apparently were responsible for the high mortality on July 17 and August 1.

Salinity was probably not a major factor in mortality as it was only 37‰ during the periods of intensive mortality.

TABLE 2. **List of Species Found in the Dana Point Impoundment, Including All Observed Mortalities July 3 to September 8, 1969. Species Were Identified and Listed Using Roedel (1953), with the Exception of the Last Two Species. Asterisks Indicate Special Estimated to Have Undergone Total Mortality (see text).**

Species	Common name	Number of mortalities		
		Large pool	Small pool	Total
Elasmobranchs				
Heterodontus francisci	California horn shark	1	0	1
Triakis semifasciata	Leopard shark	0	1	1
Mustelus californicus	Gray smoothhound	2	9	11
Squatina californica	California angel shark	1	0	1
Rhinobatos productus	Shovelnose guitarfish	0	1	1
Platyrhinoidis triseriata	California thornback	1	0	1
Torpedo californica	Pacific electric ray	1	0	1
Urolophus halleri	Round stingray	4	291	295
Gymnura marmorata	California butterfly ray	3	7	10
Myliobatis californicus	Bat ray	6	15	21
Teleosts				
*Engraulis mordax**	Northern anchovy	6	3	9
*Anchoa compressa**	Deepbody anchovy	6	140	146
Gymnothorax mordax	California moray	2	5	7
Paralichthys californicus	California halibut	1	16	17
Hypsopsetta guttulata	Diamond turbot	20	685	705
Symphurus atricauda	California tonguefish	2	0	2
Morone saxatilis	Striped bass	8	0	8
Paralabrax clathratus	Kelp bass	77	291	368
Paralabrax nebulifer	Sand bass			
Paralabrax maculatofasciatus	Spotted bass	3	27	30
*Atherinops affinis**	Topsmelt	8	5	13
*Sphyraena argentea**	California barracuda	262	1	263
*Xenistius californiensis**	California salema	9	21	30
Anisotremus davidsoni	California sargo	8	172	180
Scriphus politus	Queenfish	3	29	32
Menticirrhus undulatus	California corbina	4	49	53
*Genyonemus lineatus**	White croaker	198	215	413
*Hyperprosopon argenteum**	Walleye surfperch	29	1	30
*Amphistichus argenteus**	Barred surfperch	36	14	50
*Phanerodon furcatus**	White seaperch	94	35	129
*Rhacochilus vacca**	Pile perch	7	12	19
*Embiotoca jacksoni**	Black perch	253	115	368
*Cymatogaster aggregata**	Shiner perch	31	7	38
*Micrometrus minimus**	Dwarf perch	1	0	1
*Hypsypops rubicunda**	Garibaldi	95	16	111
*Oxyjulis californica**	Señorita	1	0	1
*Halichoeres semicinctus**	Rock wrasse	40	9	49
Girella nigricans	Opaleye	1	24	25
*Medialuna californiensis**	Halfmoon	6	0	6
Sebastes spp.	Rockfish	4	2	6
Scorpaena guttata	Sculpin	19	10	29
Porichtys myriaster	Slim midshipman	2	4	6
*Heterostichus rostratus**	Kelpfish	35	1	36
Otophidiam scrippsae	Cusk-eel	7	1	8
Sygnathus griseolineatus	Pipefish	0	1	1
Totals		1,296	2,235	3,531

* Species estimated to have undergone total mortality during the study.

Of the species exhibiting total mortality during the study, the surfperch as a group were the least hardy (Table 3, Group 1). These fish underwent an intensive die-off which was virtually complete by July 18. Only kelpfish and California barracuda showed similar mortality characteristics. Black perch seemed to be the most hardy and walleye surfperch the least hardy of the Embiotocidae.

White croaker, rock wrasse, and garibaldi, although exhibiting total mortality, are more hardy than the others in this group. Our data indicate a slow steady attrition for these three species rather than an intensive die-off. The garibaldi were the most hardy of the three, and thus of any of the species showing total mortality. A considerable number

TABLE 3. **Relative Hardiness of Fishes in Main Pool.**

Scientific name	Common name	(1969)* Estimated dates of: 50% mortality	95% mortality
Group 1—Least hardy species			
1. *Heterostichus rostratus*	Giant kelpfish	7/5	7/13
2. *Hyperprosopon argenteum*	Walleye surfperch	7/12	7/15
3. *Sphyraena argentea*	California barracuda	7/13	7/15
4. *Rhacochilus racea*	Pile perch	7/14	7/15
5. *Phanerodon furcatus*	White seaperch	7/14	7/15
6. *Amphistichus argenteus*	Barred surfperch	7/13	7/16
7. *Cymatogaster aggregata*	Shiner perch	7/13	7/17
8. *Embiotoca jacksoni*	Black perch	7/17	7/18
9. *Genyonemus lineatus*	White croaker	7/17	8/11
10. *Halichoeres semicinctus*	Rock Wrasse	7/13	8/14
11. *Hypsypops rubicunda*	Garibaldi	8/1	8/21
Group 2			
1. *Anchoa compressa*	Deepbody anchovy	7/12	7/14
2. *Myliobatis californicus*	Bat ray	7/11	7/11
3. *Neoustius californiensis*	Salema	7/9	7/15
4. *Scorpaena guttata*	Sculpin	7/11	7/15
5. *Menticirrhus undulatus*	Corbina	7/14	7/18
6. *Anisotremus davidsoni*	Sargo	7/15	7/18
7. *Seriphus politus*	Queenfish	7/17	7/18
8. *Paralabrax nebulifer*	Sand bass	7/18	7/18
9. *P. clathratus*	Kelp bass	7/18	7/18
10. *P. maculatofasciatus*	Spotted sandbass	7/18	7/20
11. *Gymnura marmorata*	Butterfly ray	7/20	7/20
12. *Urolophus halleri*	Round stingray	7/20	7/20
13. *Paralichthys californicus*	California halibut	7/20	7/20
14. *Girella nigricans*	Opaleye	7/18	7/25
15. *Hypsopsetta guttulata*	Diamond turbot	7/20	7/25

* Group 1 dates were from main pool populations, Group 2 dates from small pool populations (see text).

of early garibaldi deaths were caused by their peculiar behavior. The garibaldi would often not leave the rock ledges until stranded by draw down in shallow pools, where high temperature presumably killed them. Some 75 garibaldi were rescued from these pools and released in the ocean, so the number of garibaldi in the impoundment was closer to 200 than 111.

Fifteen species underwent little or no mortality in the main pool and are thus considered the most tolerant (Table 3, Group 2). Diamond turbot, opaleye, butterfly ray, round stingray and California halibut seemed to be most hardy of all 26 species ranked. Of the hardy species only the sand bass had many main pool deaths (21% of its total mortality).

Moray eels and some sharks seemed to be very hardy, but were counted in insufficient numbers to be ranked in Table 3.

In general, the surfperch were the least hardy fish studied. Every surfperch species displayed 100% mortality during the study. These were followed by a mixed group of fishes which were more or less hardy. The most hardy upright swimming fish were the three bass (*Paralabrax spp.*), and opaleye. The overall most hardy "group" of fish were the flatfish, both elasmobranchs (butterfly and round rays) and teleosts (California halibut and diamond turbot). Very few deaths in the dense population of main pool flatfish occurred. At the time of termination of the study, many sand bass, round stingrays, halibut and turbot were observed; these were caught in large numbers in a 20 ft seine, along with some sargo and queenfish, and occasional specimens of other surviving species.

CONCLUSIONS

Our study indicates that oxygen levels below 3.0 ppm might be fatal to many species of fish, especially when accompanied by temperatures 6 to 8 C above normal. Temperatures of 30 to 32 C (9 to 12 C above normal) also were responsible for high fish mortality, even with high oxygen concentrations.

It appears that changes in oxygen levels and water temperatures of the magnitude described here could significantly alter the vertebrate faunistic makeup of inshore waters.

The group least tolerant to such changes was the Embiotocidae. Surfperches are some of the most important fishes in southern California coastal waters from the standpoint of numbers of species and individuals. A temperature increase of 9 to 12 C would result in the removal of a large number of fishes from the inshore community and is bound to have a great affect on the remaining species, both vertebrate and invertebrate.

The impact of coastal organic and thermal pollution therefore should be carefully considered.

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We wish to acknowledge the tireless assistance of James Miller, Zoology Museum Curator at U.C.L.A., who helped with both the mortality census and water analysis throughout much of the investigation. We are also indebted to Garfield House for field assistance, and David Soltz for helping with fish identification.

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PROTEIN DIFFERENCES IN THE EYE LENS CORTEX AND NUCLEUS OF INDIVIDUAL CHANNEL ROCKFISH, *SEBASTOLOBUS ALASCANUS*[1]

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Albumins and globulins were extracted from the aqueous humor, lens cortex, and various layers of the lens nucleus of individual channel rockfish, *Sebastolobus alascanus*. Protein from the nucleus was the most resistant to denaturation and produced the simplest electrophoretic pattern. These findings suggest that electrophoretic patterns of nuclear lens proteins would be useful in a study of the rockfish family, which is taxonomically complex.

INTRODUCTION

The rockfish family (Scorpaenidae) is a taxonomically diverse and complex group (Phillips, 1957; Barrett, Joseph and Moser, 1966; Tsuyuki et al, 1968). Preliminary to a broad study of this family by electrophoretic separation of lens proteins, it was decided that a study of the proteins of different parts of the lens and the aqueous humor from one representative species should be conducted. Because of availability, the channel rockfish, *Sebastolobus alascanus*, was selected. Although the proteins of different lens layers have been studied in various fish species and in other vertebrates (most recently, Cobb, 1968; Gutiérrez, 1969; Dohrn, 1970), a study of this type has not previously been conducted on any rockfish.

MATERIALS AND METHODS

Experiment I

Electrophoretic patterns were prepared of protein from the cortices and nuclei of lenses taken from six fresh channel rockfish. One lens was processed fresh, and the remainder after being given the following individual treatments: (i) frozen once; (ii) frozen, thawed, and re-frozen; (iii) left in a decomposing fish head in non-circulating sea water at room temperature for 5 days; (iv) stored outdoors in the shade for 5 days; and (v) stored outdoors in the sun for 5 days.

Experiment II

Electrophoretic patterns of proteins of the aqueous humor, cortex, and four different layers of the lens nucleus from a fresh-frozen channel rockfish were prepared. The outermost layer of the nucleus was purposely not cleaned of all adherent cortical tissue.

In both experiments, electrophoretic patterns of proteins were prepared by the method described by Smith (1966) and by Smith and Goldstein (1967). By this method, proteins are solubilized first in distilled water and then in physiological saline solution, to obtain both

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albumins and globulins. Electrophoresis is for 20 min at 300 v (constant) on $4\frac{1}{2}$ inch Gelman Sepraphore III cellulose acetate membranes in a Model "R" Durrum cell (without folding rack and bridge), utilizing a barbital buffer of pH 8.6 and ionic strength 0.050–0.052. The protein stain-fixative is Ponceau red 3R dye (4 g)—5% trichloroacetic acid (1,000 ml). Background stain is removed with absolute methanol after a brief rinse in 5% acetic acid. Membranes with protein zones are allowed to fuse to microscope slides after 15 sec immersion in a solution of 80 parts absolute methanol and 20 parts glacial acetic acid. Scanning of the proteins is by a Photovolt Deniscord Densitometer adjusted by "full light" and "dark point" controls to produce a miniature graph, and modified: (i) for increased resolution by reduction in the size of the light slit to $\frac{2}{16}$ inch in length and $\frac{3}{4}$ of its regular width, and (ii) to produce a smoother graph by the insertion of a piece of electrophoresis paper over the light slit.

RESULTS AND DISCUSSION

Experiment I

Electrophoretic separation of protein from the nuclei of lenses exposed to different physical conditions produced simple and almost identical patterns (Figure 1). Cortical protein patterns, by contrast, are more complex and variable. For example, a pair of proteins that are close together and approximately half way between the zone of sample application and the farthest migrating protein are clearly visible in cortical patterns A–D. However, the lesser migrating fraction of this pair is less evident in E, and finally cannot be seen in F. The farthest migrating protein also is variable in the cortical patterns.

Thus, protein in the lens cortex is demonstrated less stable than protein in the nucleus. The sensitivity of cortical proteins is attributed to the cortex being a metabolizing tissue and, therefore, containing enzymes and proteins in the process of "turn-over" that are easily altered. In addition, labile proteins of the aqueous and vitreous humors are present in the cortex (Monahan, 1953; Rao et al, 1955; Davson, 1963), possibly entering through channels or pores that may exist in the lens capsule (Monahan, 1953; for a review, see Smith, 1970b). The lens nucleus, by contrast, is inert and contains primarily proteins that are structural and sclerosed; these proteins resist breakdown. Resistance of nuclear lens protein to heat was previously demonstrated in yellowfin tuna, *Thunnus albacares* (Smith, 1965), and more recently in yellowfin tuna and in bigeye tuna, *T. obesus* (Smith, 1970a).

Experiment II

Electrophoretic separation of protein from the cortex and nucleus, regardless of layer, produced distinctly different patterns (Figure 2), as in experiment I. In addition, the patterns show that: (i) there is a similarity between aqueous humor and cortex, in that the patterns of both tissues have five fractions with approximately the same mobilities, with one exception—that being the fraction closest to the cathode; (ii) there is a complex protein composition of whole lens (represented by outermost nuclear layer with adherent cortex); and (iii) there are three major fractions in all layers of pure lens nucleus. Patterns pro-

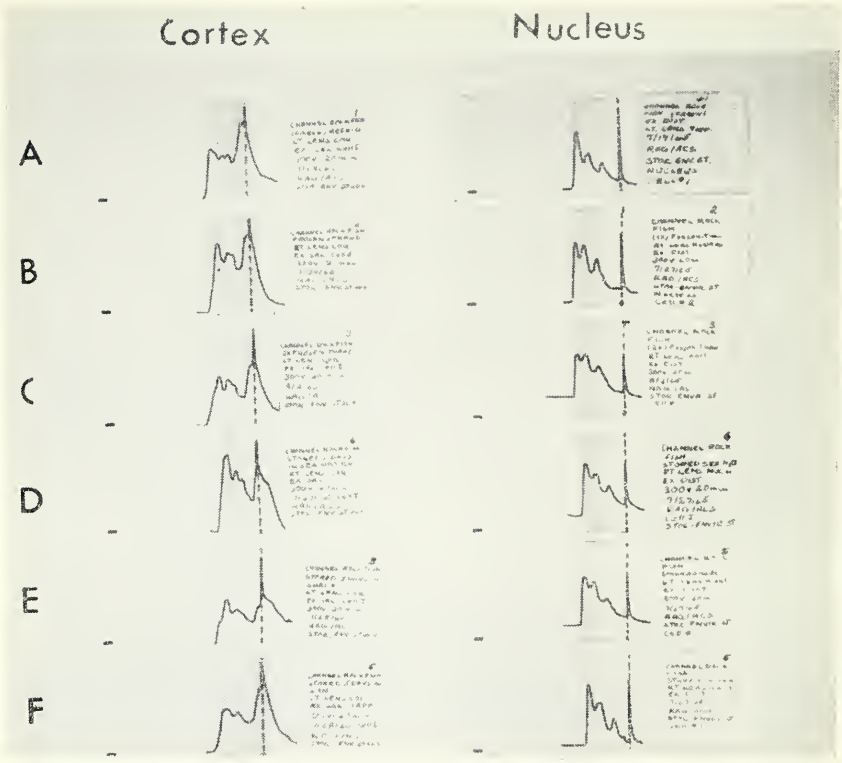

FIGURE 1. Electrophoretic patterns of protein from the cortex and nucleus of channel rockfish lenses that were: fresh (A); frozen once (B); frozen, thawed, and refrozen (C); left in a decomposing fish head in noncirculating sea water at room temperature for five days (D); stored outdoors in the shade for five days (E); and stored outdoors in the sun for five days (F). The dashed line indicates the zone of sample application, to the left of which is the cathode.

duced by the more superficial nuclear lens layers are more intensely stained overall, but in all patterns of nuclear lens, the farthest-migrating fraction stained the darkest.

In both experiments, the electrophoretic patterns demonstrated a predominantly cathodal migration of lens proteins. However, in electrophoretic patterns of cortical lens protein from another species, the Pacific albacore, *Thunnus alalunga*, a discrete anodal-migrating protein was noted (Smith, 1966). This protein could be serum albumin, since this molecule has a highly electronegative charge; readily traverses the lens capsule (Orzalesi and Pirodda, 1955); and might normally be in eye humor, as are some other serum proteins (Utter and Hodgins, 1969).

SUMMARY AND CONCLUSIONS

Albumins and globulins were extracted from the aqueous humor and the lens cortices and nuclei of individual channel rockfish. Protein from the nuclei, where staining indicated that it is concentrated in the outer layers, was more resistant to denaturation and produced a simpler electrophoretic pattern than cortical protein.

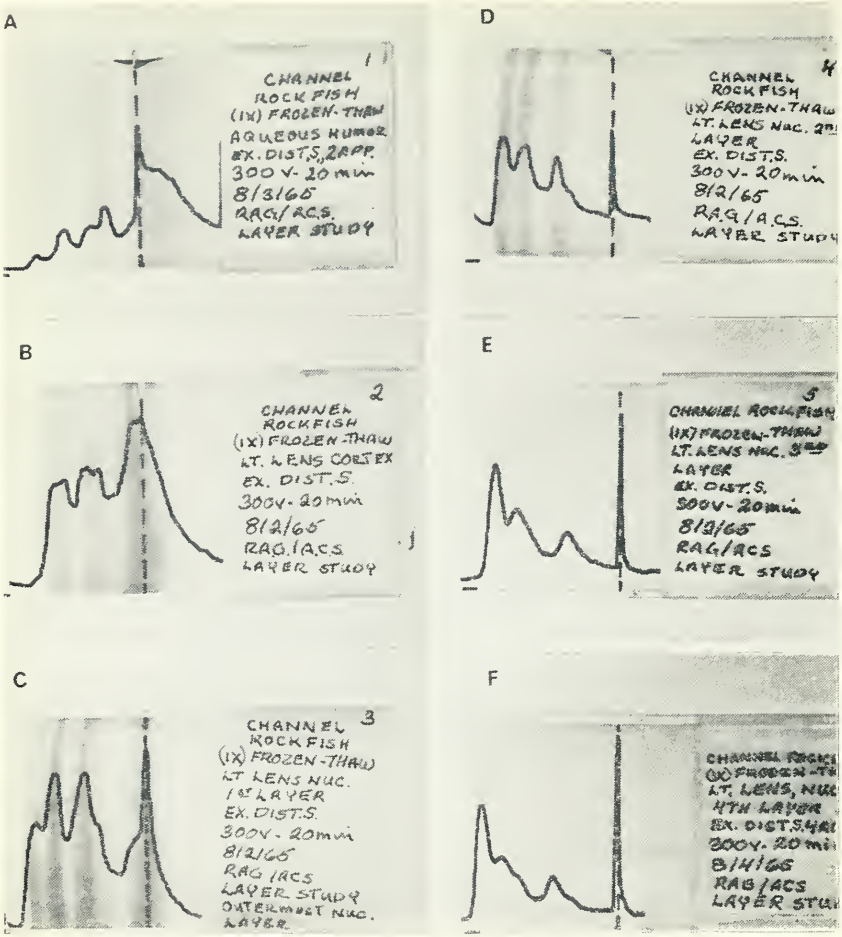

FIGURE 2. Electrophoretic patterns of protein from the aqueous humor (A); cortex (B); outermost layer of nucleus, with some adherent cortex (C); and progressively deeper layers of the nucleus (D-F) of a single channel rockfish lens. The dashed line indicates the same as in Figure 1.

These findings indicate the lens nucleus, in contrast with either whole lens or only the cortex, would provide the most reliable and readily analyzable protein for a taxonomic study, by electrophoresis, of the rockfish family.

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REVISION OF THE AGE COMPOSITION OF THE SOUTHERN CALIFORNIA CATCH OF PACIFIC MACKEREL FOR THE 1958–59 THROUGH 1963–64 SEASONS[1]

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Errors in age assignments of the Pacific Mackerel, *Scomber japonicus* (Houttuyn), catch off southern California for the 1958–59 through 1963–64 seasons were found. When these were corrected, many previously aged fish were assigned to older age groups which resulted in the apparent increase in growth rate being reduced to a level comparable with the 1939 through 1957 period. Of particular importance was a 58% decrease in total estimated number of age-group 0 fish and a subsequent 30% increase in age-group I fish.

INTRODUCTION

Obvious discrepancies in the lengths of "zero-aged" Pacific mackerel from the 1958–59 through 1963–64 seasons were discovered in 1968 by Richard H. Parrish. Inspection of the length-frequencies for assigned ages indicated that the zero and one-year-olds ranged from 80 to 117 quarter-centimeters in length with almost complete overlap of the modal groups. The zero-age fish were landed from May through August at a size normally found in one-year-old fish. Fitch (1951) reported modes of 71 quarter-centimeters in July and 73 quarter-centimeters in August for Pacific mackerel in their first calendar year. In their second year he reports they usually reach a mode of about 105 quarter-centimeters.

Because of the foregoing considerations we re-read all the otoliths from the 1958–59 through 1963–64 seasons and found the published age composition to be in error. This erroneous under-aging of mackerel by Hyatt (1962, 1965) and Messersmith and Hyatt (1965) resulted in an apparent increase in the growth rate and a reduction of the calculated numbers of older fish in the catch.

This report, therefore, revises the published age composition of Pacific mackerel for the 1958–59 through 1963–64 seasons.

METHODS

As an initial check on age assignments made for the 6 seasons, we independently read all the otoliths from the 1960–61 season. We had never previously read otoliths together and purposely avoided establishing joint criteria for these readings.

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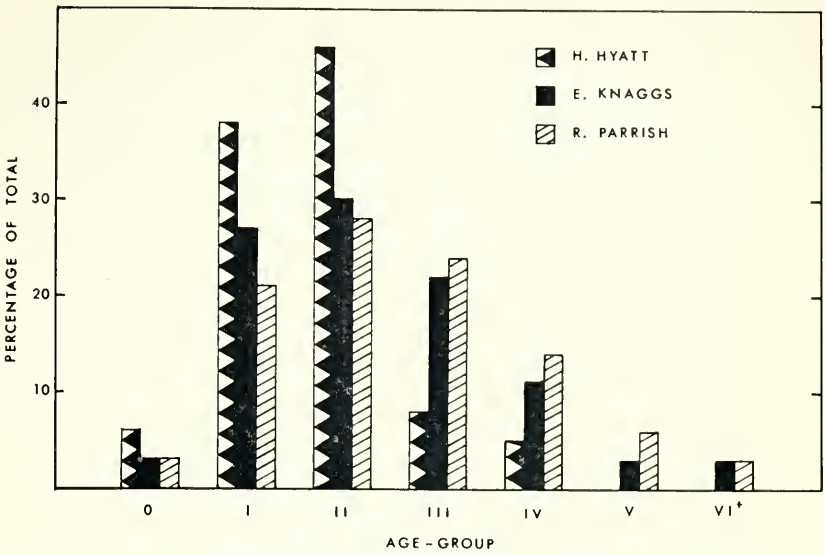

FIGURE 1. A comparison of the 1960–61 season age assignments by different otolith readers.

The results show a relatively close agreement between our independent readings and considerable disagreement between our readings and the original age assignments used in the literature (Figure 1). There was a marked increase in older fish in our readings. This increase in older fish decreased the mean size per age-group to levels comparable to those reported by Fitch (1951).

Because of our disagreements with the age assignments in the 1960–61 season it became necessary to re-read the otoliths from the other seasons. However, due to the large number of otoliths taken during the 1958–59 through 1963–64 seasons (3,016), we decided that all otoliths would not be read by each author. Instead, each read approximately one half of the otoliths. When disagreement occurred between these readings and the age assignments used in the published material the other author read these disputed otoliths. If this additional reading agreed with either the published material or the first re-reading, this age was accepted. If all three readings were in disagreement, the authors jointly agreed to an age or the otoliths in disagreement were omitted. Only 17 otoliths of the 3,016 taken during the six seasons were thus omitted as unreadable (Appendixes A, B, C, D, E, F).

TABLE 1. **Estimated Number of Pacific Mackerel in the Southern California Commercial Catch Age-Group and Season**

Age groups	1958–59 Season				1959–60 Season				1960–61 Season			
	Original		Revised		Original		Revised		Original		Revised	
	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
0	23,922	60.7	16,464	41.8	30,000	45.8	1,547	2.4	5,100	10.1	2,498	5.0
I	1,511	3.8	1,277	3.2	30,799	47.1	56,795	86.8	21,756	43.1	17,680	35.1
II	4,533	11.5	5,915	15.0	2,692	4.1	4,211	6.4	20,104	39.9	19,889	39.4
III	7,300	18.5	10,865	27.6	1,081	1.7	1,050	1.6	3,245	6.4	7,681	15.2
IV	1,687	4.3	3,493	8.9	751	1.1	1,283	2.0	131	0.3	2,008	4.0
V	295	0.8	1,125	2.9	120	0.2	419	0.6	89	0.2	415	0.8
VI+	182	0.4	291	0.7	--	--	139	0.2	--	--	258	0.5
Totals	39,430	100.0	39,430	100.1	65,443	100.0	65,444	100.0	50,428	100.0	50,429	100.0

Age groups	1961–62 Season				1962–63 Season				1963–64 Season			
	Original		Revised		Original		Revised		Original		Revised	
	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
0	24,800	36.3	17,997	26.3	8,353	16.6	52	0.1	152	0.5	41	0.1
I	20,391	29.9	25,621	37.6	19,637	39.0	26,006	51.6	5,752	18.1	2,523	8.0
II	15,162	22.2	13,066	19.1	15,302	30.4	11,987	23.8	19,031	60.0	14,642	46.2
III	7,004	10.3	9,315	13.6	6,360	12.6	8,650	17.2	5,142	16.2	8,505	26.8
IV	757	1.1	1,958	2.9	746	1.5	3,326	6.6	1,599	5.0	5,190	16.4
V	117	0.2	205	0.3	--	--	342	0.7	22	0.1	704	2.2
VI+	--	--	69	0.1	--	--	35	--	--	--	90	0.3
Totals	68,231	100.0	68,231	99.9	50,398	100.1	50,398	100.0	31,698	99.9	31,698	100.0

TABLE 2. **Estimated Number of Pacific Mackerel by Year-Class (in thousands) in the Southern California Commercial Catch**

Season	Year-class											
	1958		1959		1960		1961		1962		1963	
	Original	Revised	Original	Revised	Original	Revised	Original	Revised	Original	Revised	Original	Revised
1958–59	23,922	16,464										
1959–60	30,799	56,795	30,000	1,547								
1960–61	20,104	19,889	21,756	17,680	5,100	2,498						
1961–62	7,004	9,315	15,162	13,066	20,391	25,621	24,800	17,997				
1962–63	746	3,326	6,360	8,650	15,302	11,987	19,637	26,006	8,353	52		
1963–64	22	704	1,599	5,190	5,142	8,505	19,031	14,642	5,752	2,523	152	44
Totals	82,597	106,493	74,877	46,133	45,935	48,611	63,468	58,645	14,105	2,575	152	44

TABLE 3. **Age and Year-Class Composition of the Pacific Mackerel Catch in Southern California During 1958–59 Through 1963–64 Seasons**

	Estimated number and pounds of fish in thousands by age							
	0	I	II	III	IV	V	VI+	Totals
1958–59 Season								
Year-class	1958	1957	1956	1955	1954	1953	----	
Thousands of fish	16,464	1,277	5,915	10,865	3,493	1,125	291	39,430
Percent	41.8	3.2	15.0	27.6	8.9	2.9	0.7	100.1
Thousands of pounds	4,454	664	4,283	9,769	3,854	1,358	394	24,776
Percent	18.0	2.7	17.3	39.4	15.6	5.5	1.6	100.1
1959–60 Season								
Year-class	1959	1958	1957	1956	1955	1954	----	
Thousands of fish	1,547	56,795	4,211	1,050	1,283	419	139	65,444
Percent	2.4	86.8	6.4	1.6	2.0	0.6	0.2	100.0
Thousands of pounds	505	32,638	4,104	1,302	1,796	674	263	41,282
Percent	1.2	79.1	9.9	3.2	4.4	1.6	0.6	100.0
1960–61 Season								
Year-class	1960	1959	1958	1957	1956	1955	----	
Thousands of fish	2,498	17,680	19,889	7,681	2,008	415	258	50,429
Percent	5.0	35.1	39.4	15.2	4.0	0.8	0.5	100.0
Thousands of pounds	562	7,661	18,010	9,012	2,751	639	439	39,074
Percent	1.4	19.6	46.1	23.1	7.0	1.6	1.1	99.9
1961–62 Season								
Year-class	1961	1960	1959	1958	1957	1956	----	
Thousands of fish	17,997	25,621	13,066	9,315	1,958	205	69	68,231
Percent	26.4	37.6	19.1	13.6	2.9	0.3	0.1	100.0
Thousands of pounds	5,659	13,732	11,454	10,407	2,529	287	124	44,192
Percent	12.8	31.1	25.9	23.5	5.7	0.7	0.3	100.0
1962–63 Season								
Year-class	1962	1961	1960	1959	1958	1957	----	
Thousands of fish	52	26,006	11,987	8,650	3,326	342	35	50,398
Percent	0.1	51.6	23.8	17.2	6.6	0.7	---	100.0
Thousands of pounds	32	18,206	11,549	10,386	4,499	522	59	45,253
Percent	0.1	40.2	25.5	23.0	9.9	1.2	0.1	100.0
1963–64 Season								
Year-class	1963	1962	1961	1960	1959	1958	----	
Thousands of fish	44	2,523	14,642	8,505	5,190	704	90	31,698
Percent	0.1	8.0	46.2	26.8	16.4	2.2	0.3	100.0
Thousands of pounds	19	1,660	14,327	9,974	6,985	1,104	141	34,210
Percent	0.1	4.9	41.9	29.2	20.4	3.2	0.4	100.1

TABLE 4. Number of Pacific Mackerel Landed by Age-Group for Each Year-Class From the 1950–51 Through 1963–64 Seasons *

Year-class	Age Group						
	0 Thousands	I Thousands	II Thousands	III Thousands	IV Thousands	V Thousands	Totals Thousands
1950	6	1,583	521	583	71	15	2,779
1951	769	46	475	208	204	62	1,764
1952	86	676	3,893	6,021	3,641	2,302	16,619
1953	12,237	40,036	21,156	14,641	8,160	1,125	97,355
1954	564	3,562	14,976	11,332	3,493	419	34,346
1955	4,237	49,429	30,487	10,865	1,283	415	96,716
1956	21	6,228	5,915	1,050	2,008	205	15,427
1957	1,386	1,277	4,211	7,681	1,958	342	16,855
1958	16,464	56,795	19,889	9,315	3,326	704	106,493
1959	1,547	17,680	13,066	8,650	5,190	----	46,133
1960	2,498	25,621	11,987	8,505	----	----	48,611
1961	17,997	26,006	14,642	----	----	----	58,645
1962	52	2,523	----	----	----	----	2,575
1963	44	----	----	----	----	----	44

* For data prior to the 1950 year-class see Calif. Fish and Game (46)2:187.

TABLE 5. **Pounds of Pacific Mackerel Landed by Age-Group for Each Year-Class From the 1950–51 Through the 1963–64 Seasons** *

Year-class	Age group						
	0 Thousands of pounds	I Thousands of pounds	II Thousands of pounds	III Thousands of pounds	IV Thousands of pounds	V Thousands of pounds	Totals Thousands of pounds
1950	1	802	474	687	90	24	2,078
1951	252	34	483	234	244	94	1,341
1952	33	463	3,063	6,034	4,394	3,112	17,099
1953	4,358	23,175	16,990	14,973	10,197	1,358	71,051
1954	94	1,964	11,722	12,294	3,854	674	30,602
1955	1,270	25,940	24,552	9,769	1,796	639	63,966
1956	5	4,222	4,283	1,302	2,751	287	12,850
1957	466	664	4,104	9,012	2,529	522	17,297
1958	4,454	32,638	18,010	10,407	4,499	1,104	71,112
1959	505	7,661	11,454	10,386	6,985	----	36,991
1960	562	13,732	11,549	9,974	----	----	35,817
1961	5,659	18,206	14,327	----	----	----	38,192
1962	32	1,660	----	----	----	----	1,692
1963	19	----	----	----	----	----	19

* For data prior to the 1950 year-class see Calif. Fish and Game (46)2:188.

AGE COMPOSITION ADJUSTMENTS

Changes in otolith readings resulted in significant adjustments to the catch age composition for the six seasons (Table 1). A major adjustment is the 58% decrease in the total estimated number of age-group 0 fish and a subsequent increase in age-group I fish of 30%. The original reader apparently failed to take the May 1st birthdate (Fitch, 1951) into consideration and consequently many fish without a completed annulus taken on or after that date were not classified as I's. Age-group II was the least affected by the revised age assignments even though this was one of the major contributing groups. Age-groups III, IV, V, and VI+ were extensively altered and there were large increases in numbers in all cases.

The 1958 and 1959 year-classes were originally similar in estimated numbers of fish landed; however, in the revised estimates the 1958 year-class is a much greater contributor to the fishery (Table 2).

REVISED AGE COMPOSITION

The southern California Pacific mackerel landings for the seasons 1958–59 through 1963–64 were characterized by two major year-classes (1958 and 1961) which combined to furnish 54% of the total estimated 306.5 million fish landed (Tables 3 and 4). During the 1959–60 season the fishery depended almost entirely on the 1958 year-class.

For the period of this report, zero and one-year-olds contributed 55% by number of the total catch. Age-groups IV and older contributed only 7%. The 1958 year-class contributed over 106 million fish to the fishery (Table 4) and was the most dominant year-class since 1947. The 1947 year-class remained the most abundant ever recorded having yielded 150 million fish.

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APPENDIX A—**Length Frequency of Pacific Mackerel Sampled During 1958–59 Season**

½ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
1	1	1	--	--	--	--	--	--	1
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
75	--	--	--	--	--	--	--	--	--
6	3	--	--	--	--	--	--	--	--
7	7	3	--	--	--	--	--	--	3
8	8	--	--	--	--	--	--	--	--
9	11	4	--	--	--	--	--	--	4
80	15	3	--	--	--	--	--	--	3
1	26	2	--	--	--	--	--	--	2
2	33	3	--	--	--	--	--	--	3
3	24	6	--	--	--	--	--	--	6
4	31	4	--	--	--	--	--	--	4
85	26	9	--	--	--	--	--	--	9
6	29	3	--	--	--	--	--	--	3
7	32	6	--	--	--	--	--	--	6
8	45	9	--	--	--	--	--	--	9
9	42	9	--	--	--	--	--	--	9
90	56	12	--	--	--	--	--	--	12
1	43	4	--	--	--	--	--	--	4
2	88	4	--	--	--	--	--	--	4
3	76	8	--	--	--	--	--	--	8
4	101	15	1	--	--	--	--	--	16
95	117	18	--	--	--	--	--	--	18
6	120	10	--	--	--	--	--	--	10
7	132	10	1	--	--	--	--	--	11
8	129	13	2	--	--	--	--	--	15
9	138	11	--	--	--	--	--	--	11
100	130	13	1	--	--	--	--	--	14
1	154	18	--	--	--	--	--	--	18
2	159	9	--	--	--	--	--	--	9
3	137	16	2	--	--	--	--	--	18
4	113	11	--	--	--	--	--	--	11
105	103	8	1	--	--	--	--	--	9
6	100	18	1	--	--	--	--	--	19
7	90	13	1	--	--	--	--	--	14
8	90	12	2	--	--	--	--	--	14
9	67	9	2	--	--	--	--	--	11
110	45	6	3	--	--	--	--	--	9
1	39	8	--	1	--	--	--	--	9
2	29	7	1	--	--	--	--	--	8
3	27	6	8	2	--	--	--	--	16
4	30	--	4	2	--	--	--	--	6
115	30	2	6	3	--	--	--	--	11
6	28	3	3	2	--	--	--	--	8
7	36	--	6	3	--	--	--	--	9
8	49	2	11	3	1	--	--	--	17
9	55	--	3	4	2	--	--	--	9
120	58	--	6	10	2	--	--	--	18
1	58	--	1	6	1	--	--	--	8
2	79	--	3	8	2	--	--	--	13
3	84	--	1	3	1	--	--	--	5
4	109	--	4	13	5	--	--	--	22
125	101	--	--	10	5	--	--	--	15
6	152	--	--	8	6	--	--	--	14
7	139	--	--	2	3	--	--	--	5
8	176	--	--	6	15	--	--	--	21
9	181	--	1	9	11	1	--	--	22
130	165	--	--	6	11	--	--	--	17
1	182	--	--	6	18	1	1	--	26
2	165	--	1	6	14	--	--	--	21
3	155	--	--	3	12	1	--	--	16
4	136	--	--	1	8	1	--	--	10
135	134	--	--	4	9	1	--	--	14

APPENDIX A—**Length Frequency of Pacific Mackerel Sampled During 1958–59 Season**—Continued

¼ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
6	135	--	--	2	9	2	--	--	13
7	112	--	--	2	13	3	--	--	18
8	122	--	--	1	14	4	1	--	20
9	104	--	--	--	5	2	--	1	8
140	105	--	--	1	11	6	--	--	18
1	100	--	--	--	11	6	1	--	18
2	96	--	--	1	10	12	1	--	24
3	75	--	--	1	1	7	--	--	9
4	63	--	--	1	1	5	2	--	9
145	59	--	--	1	1	5	3	--	10
6	66	--	--	--	4	9	8	1	22
7	44	--	--	--	--	6	3	--	9
8	44	--	--	--	3	6	5	--	14
9	29	--	--	--	--	1	2	--	3
150	26	--	--	--	--	2	3	--	5
1	18	--	--	--	--	2	3	6	11
2	12	--	--	--	1	2	--	2	5
3	18	--	--	--	--	2	2	5	9
4	9	--	--	--	--	1	1	3	5
155	3	--	--	--	--	1	--	1	2
6	12	--	--	--	1	1	3	3	8
7	2	--	--	--	--	--	--	--	--
8	1	--	--	--	--	--	1	--	1
9	3	--	--	--	--	--	1	2	3
160	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	1	--	--	--	--	--	--	1	1
4	--	--	--	--	--	--	--	--	--
165	1	--	--	--	--	--	--	1	1
Total	6,178	328	76	131	211	90	41	26	903
Mean		98.4	114 6	125.8	133.8	143.6	148.0	153.4	120.4

APPENDIX B—Length Frequency of Pacific Mackerel Sampled During 1959–60 Season

¼ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
75	--	--	--	--	--	--	--	--	--
6	1	--	--	--	--	--	--	--	--
7	2	2	--	--	--	--	--	--	2
8	2	1	--	--	--	--	--	--	1
9	1	--	--	--	--	--	--	--	--
80	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	2	2	--	--	--	--	--	--	2
85	1	1	--	--	--	--	--	--	1
6	1	1	--	--	--	--	--	--	1
7	1	1	--	--	--	--	--	--	1
8	1	1	--	--	--	--	--	--	1
9	1	--	2	--	--	--	--	--	2
90	3	--	1	--	--	--	--	--	1
1	7	1	3	--	--	--	--	--	4
2	7	--	1	--	--	--	--	--	1
3	8	--	4	--	--	--	--	--	4
4	20	2	8	--	--	--	--	--	10
95	37	2	9	--	--	--	--	--	11
6	58	--	6	--	--	--	--	--	6
7	89	1	10	--	--	--	--	--	11
8	110	--	7	--	--	--	--	--	7
9	128	2	22	--	--	--	--	--	24
100	153	2	25	--	--	--	--	--	27
1	198	--	20	--	--	--	--	--	20
2	223	1	10	--	--	--	--	--	11
3	215	--	21	--	--	--	--	--	21
4	239	--	19	1	--	--	--	--	20
105	223	--	27	--	--	--	--	--	27
6	284	--	23	--	--	--	--	--	23
7	291	--	28	--	--	--	--	--	28
8	269	--	24	--	--	--	--	--	24
9	246	--	22	--	--	--	--	--	22
110	223	--	10	2	--	--	--	--	12
1	243	--	17	--	--	--	--	--	17
2	211	--	23	--	--	--	--	--	23
3	190	--	20	--	--	--	--	--	20
4	183	--	19	--	--	--	--	--	19
115	156	--	22	--	--	--	--	--	22
6	134	--	17	1	--	--	--	--	18
7	133	--	15	--	--	--	--	--	15
8	122	--	15	4	--	--	--	--	19
9	114	--	21	1	--	--	--	--	22
120	91	--	18	1	--	--	--	--	19
1	108	--	18	5	--	--	--	--	23
2	80	--	12	6	--	--	--	--	18
3	65	--	6	3	--	--	--	--	9
4	76	--	6	2	--	--	--	--	8
125	66	--	9	10	--	--	--	--	19
6	41	--	6	10	--	--	--	--	16
7	44	--	4	13	1	--	--	--	18
8	34	--	2	5	3	--	--	--	10
9	21	--	--	3	1	--	--	--	4
130	24	--	1	2	3	--	--	--	6
1	23	--	--	3	3	--	--	--	6
2	24	--	2	13	2	--	--	--	17
3	14	--	--	3	5	--	--	--	8
4	21	--	--	2	2	2	--	--	6
135	5	--	--	--	2	--	--	--	2

APPENDIX B—**Length Frequency of Pacific Mackerel Sampled During 1959–60 Season**—Continued

¼ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
6	16	--	--	2	4	1	--	--	7
7	10	--	--	--	3	--	--	--	3
8	11	--	--	--	2	1	--	--	3
9	13	--	--	--	2	2	--	--	4
140	5	--	--	--	2	1	--	--	3
1	11	--	--	--	1	1	--	--	2
2	17	--	--	--	1	6	1	--	8
3	15	--	--	--	2	3	--	--	5
4	16	--	--	--	1	3	1	--	5
145	12	--	--	--	--	3	--	--	3
6	4	--	--	--	1	2	--	--	3
7	11	--	--	--	1	1	3	--	5
8	4	--	--	--	--	--	--	--	--
9	8	--	--	--	1	2	1	--	4
150	6	--	--	--	--	1	--	--	1
1	9	--	--	--	--	--	3	2	5
2	5	--	--	--	--	--	1	--	1
3	4	--	--	--	--	--	--	--	--
4	3	--	--	--	--	--	1	--	1
155	2	--	--	--	--	--	1	1	2
6	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--
160	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
165	--	--	--	--	--	--	--	--	--
6	1	--	--	--	--	--	--	1	1
Total	5,450	20	555	92	43	29	12	4	755
Mean	--	90.6	109.5	126.1	135.7	142.6	149.2	155.8	114.7

APPENDIX C—**Length Frequency of Pacific Mackerel Sampled During 1960–61 Season**

¼ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
1	2	--	--	--	--	--	--	--	--
2	6	--	--	--	--	--	--	--	--
3	5	--	--	--	--	--	--	--	--
4	15	--	--	--	--	--	--	--	--
75	22	4	--	--	--	--	--	--	4
6	28	--	--	--	--	--	--	--	--
7	19	1	--	--	--	--	--	--	1
8	22	2	--	--	--	--	--	--	2
9	17	1	--	--	--	--	--	--	1
80	15	--	--	--	--	--	--	--	--
1	7	3	--	--	--	--	--	--	3
2	4	1	--	--	--	--	--	--	1
3	2	--	--	--	--	--	--	--	--
4	1	--	--	--	--	--	--	--	--
85	1	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--
7	2	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--
9	2	1	--	--	--	--	--	--	1
90	2	--	1	--	--	--	--	--	1
1	1	--	1	--	--	--	--	--	1
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	2	1	--	--	--	--	--	--	1
95	1	--	1	--	--	--	--	--	1
6	2	--	1	--	--	--	--	--	1
7	3	--	2	--	--	--	--	--	2
8	5	--	--	--	--	--	--	--	--
9	6	--	--	--	--	--	--	--	--
100	5	--	--	--	--	--	--	--	--
1	1	--	--	--	--	--	--	--	--
2	10	--	1	--	--	--	--	--	1
3	7	1	--	--	--	--	--	--	1
4	10	--	6	--	--	--	--	--	6
105	11	--	3	--	--	--	--	--	3
6	10	--	2	1	--	--	--	--	3
7	17	--	1	--	--	--	--	--	1
8	25	1	6	--	--	--	--	--	7
9	25	--	3	--	--	--	--	--	3
110	33	--	12	--	--	--	--	--	12
1	49	--	7	--	--	--	--	--	7
2	69	--	9	--	--	--	--	--	9
3	78	--	8	1	--	--	--	--	9
4	74	--	7	2	--	--	--	--	9
115	82	--	8	1	--	--	--	--	9
6	100	--	7	2	--	--	--	--	9
7	102	--	8	3	--	--	--	--	11
8	83	--	5	7	--	--	--	--	12
9	110	--	7	7	--	--	--	--	14
120	120	--	6	11	--	--	--	--	17
1	109	--	3	8	--	--	--	--	11
2	112	--	2	11	--	--	--	--	13
3	145	--	1	8	--	--	--	--	9
4	178	--	5	14	--	--	--	--	19
125	143	--	--	12	3	--	--	--	15
6	133	--	2	10	1	--	--	--	13
7	154	--	--	15	--	--	--	--	15
8	136	--	--	7	1	--	--	--	8
9	154	--	--	11	5	1	--	--	17
130	118	--	--	7	5	--	--	--	12
1	122	--	--	7	8	--	--	--	15
2	119	--	--	2	6	--	--	--	8
3	115	--	--	4	8	2	--	--	14
4	118	--	--	6	10	--	--	--	16
135	86	--	--	3	3	--	--	--	6

APPENDIX C—**Length Frequency of Pacific Mackerel Sampled During 1960–61 Season**—Continued

¼ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
6	81	--	--	3	9	--	--	--	12
7	62	--	--	1	13	1	--	--	15
8	53	--	--	--	8	4	--	--	12
9	44	--	--	1	4	2	--	--	7
140	37	--	--	--	1	3	--	--	4
1	32	--	--	--	4	3	--	1	8
2	23	--	--	--	3	3	--	--	6
3	16	--	--	1	4	6	--	--	11
4	15	--	--	--	--	5	--	--	5
145	18	--	--	--	2	4	3	--	9
6	15	--	--	--	--	7	2	1	10
7	6	--	--	--	--	3	1	--	4
8	7	--	--	--	--	2	3	1	6
9	6	--	--	1	--	--	1	--	2
150	7	--	--	--	--	1	1	--	2
1	6	--	--	--	--	--	2	3	5
2	4	--	--	--	--	1	2	1	4
3	3	--	--	--	--	2	--	1	3
4	2	--	--	--	--	--	1	--	1
155	1	--	--	--	1	--	--	--	1
6	1	--	--	--	1	--	--	--	1
7	3	--	--	--	--	--	1	2	3
8	--	--	--	--	--	--	--	--	--
9	1	--	--	--	--	--	--	1	1
160	1	--	--	--	--	--	--	1	1
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	1	--	--	--	--	--	--	1	1
4	--	--	--	--	--	--	--	--	--
165	--	--	--	--	--	--	--	--	--
Total	3,600	16	125	167	100	50	17	13	488
Mean		83.2	113.0	125.4	135.4	143.1	149.1	153.0	126.3

APPENDIX D—**Length Frequency of Pacific Mackerel Sampled During 1961–62 Season**

½ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
1	--	--	--	--	--	--	--	--	--
2	1	--	--	--	--	--	--	--	--
3	11	--	--	--	--	--	--	--	--
4	14	--	2	--	--	--	--	--	2
75	13	--	1	--	--	--	--	--	1
6	12	--	2	--	--	--	--	--	2
7	22	--	1	--	--	--	--	--	1
8	4	--	--	--	--	--	--	--	--
9	15	--	--	--	--	--	--	--	--
80	6	1	--	--	--	--	--	--	1
1	16	1	1	--	--	--	--	--	2
2	11	--	--	--	--	--	--	--	--
3	16	--	--	--	--	--	--	--	--
4	16	2	2	--	--	--	--	--	4
85	22	3	1	--	--	--	--	--	4
6	23	--	--	--	--	--	--	--	--
7	42	1	1	--	--	--	--	--	2
8	38	3	1	--	--	--	--	--	4
9	37	3	2	--	--	--	--	--	5
90	34	2	--	--	--	--	--	--	2
1	27	1	1	--	--	--	--	--	2
2	36	2	2	--	--	--	--	--	4
3	17	2	1	--	--	--	--	--	3
4	19	1	--	--	--	--	--	--	1
95	22	5	1	--	--	--	--	--	6
6	20	1	--	--	--	--	--	--	1
7	23	3	2	--	--	--	--	--	5
8	19	--	3	--	--	--	--	--	3
9	19	3	2	--	--	--	--	--	5
100	23	1	2	--	--	--	--	--	3
1	24	4	1	--	--	--	--	--	5
2	22	--	1	--	--	--	--	--	1
3	17	1	4	--	--	--	--	--	5
4	33	--	7	1	--	--	--	--	8
105	32	1	9	--	--	--	--	--	10
6	30	1	3	--	--	--	--	--	4
7	28	--	8	--	--	--	--	--	8
8	34	--	9	--	--	--	--	--	9
9	26	--	6	--	--	--	--	--	6
110	24	--	5	--	--	--	--	--	5
1	36	--	7	--	--	--	--	--	7
2	36	--	4	1	--	--	--	--	5
3	48	--	4	1	--	1	--	--	6
4	55	--	11	3	--	--	--	--	14
115	56	--	7	2	--	--	--	--	9
6	56	--	1	--	--	--	--	--	1
7	63	--	8	2	--	--	--	--	10
8	72	--	12	2	--	--	--	--	14
9	71	--	2	2	2	--	--	--	6
120	68	--	6	7	1	--	--	--	14
1	94	--	4	5	2	--	--	--	11
2	73	--	5	7	1	--	--	--	13
3	84	--	3	5	--	--	--	--	8
4	97	--	2	6	2	--	--	--	10
125	76	--	--	4	--	--	--	--	4
6	86	--	1	6	1	--	--	--	8
7	77	--	5	6	2	--	--	--	13
8	78	--	1	4	3	--	--	--	8
9	86	--	--	2	5	--	--	--	7
130	88	--	--	2	5	--	--	--	7
1	79	--	--	4	5	--	--	--	9
2	60	--	--	4	3	--	1	--	8
3	55	--	--	2	5	1	--	--	8
4	48	--	--	2	4	1	--	--	7
135	58	--	--	3	6	--	--	--	9

APPENDIX D—Length Frequency of Pacific Mackerel Sampled During 1961–62 Season—Continued

¼ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
6	47	--	--	2	7	2	--	--	11
7	44	--	--	2	5	--	--	--	7
8	46	--	--	1	2	7	--	--	10
9	31	--	--	--	2	2	--	--	4
140	39	--	--	--	5	1	--	--	6
1	14	--	--	--	--	1	--	--	1
2	19	--	--	--	4	3	--	--	7
3	21	--	--	--	5	2	--	--	7
4	9	--	--	1	2	1	1	--	5
145	6	--	--	--	1	2	--	--	3
6	5	--	--	--	2	1	1	--	4
7	8	--	--	--	2	4	--	--	6
8	3	--	--	--	--	1	2	--	3
9	2	--	--	--	--	2	--	--	2
150	1	--	--	--	--	--	1	--	1
1	2	--	--	--	--	1	1	--	2
2	3	--	--	--	--	--	--	1	1
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
155	1	--	--	--	--	--	--	1	1
6	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--
160	--	--	--	--	--	--	--	--	--
1	1	--	--	--	--	--	--	1	1
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
165	--	--	--	--	--	--	--	--	--
Total	2,850	42	164	89	84	33	7	3	422
Mean	--	93.2	109.1	125.1	134.3	141.0	145.6	156.0	119.3

APPENDIX E—**Length Frequency of Pacific Mackerel Sampled During 1962–63 Season**

¼ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
1	1	--	--	--	--	--	--	--	--
2	2	--	--	--	--	--	--	--	--
3	1	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
95	4	--	1	--	--	--	--	--	1
6	1	--	--	--	--	--	--	--	--
7	3	--	--	--	--	--	--	--	--
8	4	--	--	--	--	--	--	--	--
9	3	--	2	--	--	--	--	--	2
100	2	--	1	--	--	--	--	--	1
1	2	--	--	--	--	--	--	--	--
2	5	--	1	--	--	--	--	--	1
3	6	--	--	--	--	--	--	--	--
4	4	--	2	--	--	--	--	--	2
105	4	--	2	--	--	--	--	--	2
6	8	--	2	--	--	--	--	--	2
7	9	--	--	--	--	--	--	--	--
8	9	--	1	--	--	--	--	--	1
9	9	--	4	--	--	--	--	--	4
110	12	--	2	--	--	--	--	--	2
1	20	--	2	--	--	--	--	--	2
2	25	--	4	--	--	--	--	--	4
3	40	--	4	--	--	--	--	--	4
4	47	2	5	--	--	--	--	--	7
115	34	--	3	1	--	--	--	--	4
6	53	--	1	--	--	--	--	--	1
7	51	--	4	1	--	--	--	--	5
8	57	--	2	1	--	--	--	--	3
9	47	--	4	4	--	--	--	--	8
120	51	--	10	1	--	--	--	--	11
1	48	--	5	2	--	--	--	--	7
2	49	--	4	1	1	--	--	--	6
3	44	--	3	5	1	--	--	--	9
4	49	--	3	--	1	--	--	--	4
125	53	--	2	4	1	--	--	--	7
6	50	--	3	3	--	--	--	--	6
7	52	--	3	2	--	--	--	--	5
8	38	--	1	2	2	--	--	--	5
9	32	--	1	3	1	--	--	--	5
130	38	--	4	3	--	--	--	--	7
1	24	--	2	--	--	--	--	--	2
2	44	--	2	4	--	1	--	--	7
3	36	--	--	3	2	--	--	--	5
4	42	--	--	1	3	--	--	--	4
135	47	--	--	3	4	--	--	--	7
6	40	--	--	4	1	1	--	--	6
7	34	--	--	2	3	--	--	--	5
8	38	--	--	--	4	--	--	--	4
9	28	--	--	--	1	3	--	--	4
140	36	--	--	--	2	3	--	--	5
1	37	--	--	1	6	4	--	--	11
2	29	--	--	--	2	2	--	--	4
3	14	--	--	--	2	3	--	--	5
4	21	--	--	--	--	1	1	--	2
145	14	--	--	--	--	2	--	--	2
6	14	--	--	--	3	2	1	--	6
7	7	--	--	1	1	2	--	--	4
8	5	--	--	--	2	--	--	--	2
9	11	--	--	1	1	1	--	--	3
150	1	--	--	--	--	--	--	--	--
1	2	--	--	--	--	--	2	--	2
2	1	--	--	--	--	--	1	--	1
3	2	--	--	--	--	1	--	--	1
4	2	--	--	--	--	--	1	1	2
155	3	--	--	--	--	2	--	--	2

APPENDIX E—**Length Frequency of Pacific Mackerel Sampled During 1962–63 Season**—Continued

¼ cm	Total sampled	0	I	II	III	IV	V	VI+	Total
6	--	--	--	--	--	--	--	--	--
7	1	--	--	--	--	1	--	--	1
8	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--
160	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--
165	--	--	--	--	--	--	--	--	--
Total	1,500	2	90	53	44	29	6	1	225
Mean		114.0	117.4	128.5	137.5	143.8	149.7	154.0	128.4

APPENDIX F—Length Frequency of Pacific Mackerel Sampled During 1963–64 Season

¼ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
90	1	--	--	--	--	--	--	--	--
1	1	--	--	--	--	--	--	--	--
2	2	--	1	--	--	--	--	--	1
3	--	--	--	--	--	--	--	--	--
4	2	--	--	--	--	--	--	--	--
95	2	--	--	--	--	--	--	--	--
6	1	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--
8	2	--	1	--	--	--	--	--	1
9	1	--	--	--	--	--	--	--	--
100	--	--	--	--	--	--	--	--	--
1	1	--	1	--	--	--	--	--	1
2	1	--	1	--	--	--	--	--	1
3	--	--	--	--	--	--	--	--	--
4	1	--	--	--	--	--	--	--	--
105	--	--	--	--	--	--	--	--	--
6	4	--	--	--	--	--	--	--	--
7	4	1	1	--	--	--	--	--	2
8	1	--	--	--	--	--	--	--	--
9	2	--	--	--	--	--	--	--	--
110	3	--	2	--	--	--	--	--	2
1	4	--	1	--	--	--	--	--	1
2	2	--	2	--	--	--	--	--	2
3	7	--	2	--	--	--	--	--	2
4	11	--	4	1	1	--	--	--	6
115	8	--	1	--	--	--	--	--	1
6	17	--	3	2	--	--	--	--	5
7	8	--	--	--	--	--	--	--	--
8	15	--	1	--	--	--	--	--	1
9	12	--	2	2	--	--	--	--	4
120	19	--	1	3	--	--	--	--	4
1	22	--	--	4	--	--	--	--	4
2	26	--	1	2	--	--	--	--	3
3	31	--	1	4	--	--	--	--	5
4	35	--	1	1	--	--	--	--	2
125	37	--	2	5	1	--	--	--	8
6	49	--	--	2	1	--	--	--	3
7	49	--	2	4	--	--	--	--	6
8	50	--	1	3	2	--	--	--	6
9	65	--	--	8	2	--	--	--	10
130	66	--	--	2	1	--	--	--	3
1	69	--	--	5	2	--	--	--	7
2	63	--	1	3	1	--	--	--	5
3	71	--	--	5	2	--	--	--	7
4	75	--	--	5	--	--	--	--	5
135	69	--	--	3	2	2	--	--	7
6	58	--	--	1	--	--	--	--	1
7	63	--	--	5	7	1	--	--	13
8	57	--	--	3	--	1	--	--	4
9	62	--	--	2	3	1	--	--	6
140	55	--	--	1	5	1	--	--	7
1	44	--	--	2	2	4	--	--	8
2	51	--	--	--	4	6	--	--	10
3	39	--	--	--	2	--	--	--	2
4	36	--	--	1	1	2	--	--	4
145	40	--	--	--	1	1	--	--	2
6	35	--	--	--	1	4	2	--	7
7	30	--	--	1	2	2	--	--	5
8	22	--	--	--	--	1	2	--	3
9	10	--	--	--	--	2	--	--	2
150	5	--	--	--	--	--	--	--	--

APPENDIX F—Length Frequency of Pacific Mackerel Sampled During 1963–64 Season—Continued

½ cm	Total sampled	O	I	II	III	IV	V	VI+	Total
1	6	--	--	--	1	--	2	1	4
2	9	--	--	--	--	3	2	1	6
3	8	--	--	--	--	--	1	--	1
4	4	--	--	--	--	1	1	--	2
155	5	--	--	--	--	--	2	--	2
6	1	--	--	--	--	1	--	--	1
7	1	--	--	--	--	--	1	--	1
8	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--
160	--	--	--	--	--	--	--	--	--
Total	1,550	1	32	80	44	33	13	2	206
Mean	--	104.0	115.9	129.6	137.1	144.3	151.4	151.5	132.8

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AGE COMPOSITION OF SARDINE LANDINGS ON THE PACIFIC COAST OF THE UNITED STATES AND MEXICO IN 1965–1966[1]

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California Department of Fish and Game

and

MAKOTO KIMURA
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California landings of the Pacific sardine, *Sardinops caeruleus* (Girard), during the 1965–66 canning season amounted to only 365 tons—the poorest catch in the history of the fishery.

Baja California landings totaled 7,235 tons. Most of the sardines processed at Ensenada came from San Sebastian Vizcaino Bay area.

The age structure of southern California landings reflected failure of the sardine population in the north to produce good year-classes. Ninety-six percent of the fish landed were age group IV and older.

INTRODUCTION

Pacific sardine landings have declined to such a low level that a moratorium on fishing was enacted in 1967. This was subsequently altered and effective November 11, 1969, 250 tons a year can be taken for use as bait.

Because of continued interest in the sardine population and its apparent interaction with the northern anchovy, *Engraulis mordax* Girard, we continue to sample the landings for age and length composition. Short reports (such as this) concerning the estimated age composition of the landings are issued periodically in California Fish and Game Quarterly. This report, the 20th of a continuing series, briefly summarizes the age composition of the 1965–1966 period landings. A more detailed discussion of the sardine fisheries off California and Baja California during this period is available in Marine Resources Reference Series; MRR reference 70-11 may be obtained from California Department of Fish and Game, Marine Resources Region, 350 Golden Shore, Long Beach, California 90802.

We wish to acknowledge the assistance of John MacGregor, National Marine Fisheries Service, and Patrick O'Brien, California Department of Fish and Game, who worked with us in our cooperative scale reading program. Eric Knaggs, California Department of Fish and Game, assisted materially in the preparation of this report.

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THE FISHERY

Fishing off California was poor with catches consisting primarily of sardines mixed with mackerel. The age structure of the catch in southern California (Table 1) reflected continuing failure of the sardine population in the north to produce good year-classes.

During the interseason, landings in central and southern California totaled 544 tons. Statewide landings during the cannery season amounted to only 365 tons, the poorest catch in the fishery's history. Thus, the statewide California total was 909 tons from March 3, 1965 to March 2, 1966. The canning season opened August 1 in central California and September 1 in southern California. The season closed on March 1 in both areas with landings allowed the following day.

The sardine fleet off central California consisted of only two large (60 ft or over) and two small purse seiners and nine lampara boats. The large purse seiners transferred their operations to southern California during the season. One cannery at Monterey and one at Moss

TABLE 1. Estimated Age and Year-Class Composition of the Sardine Catch for the 1965–66 Season

Lunar period	Catch		Numbers of fish in thousands by age and year-class							
	Tons	Estimated number	II 1963	III 1962	IV 1961	V 1960	VI 1959	VII 1958	VIII 1957	IX 1956
Central California										
"July"	15									
"August"	37									
"September"	18									
"October"										
"November"										
"December"										
"January"										
"February"										
			NO SAMPLES TAKEN							
Total Central Calif.	70									
Southern California										
"August"*	12	63	1	--	13	21	15	10	2	1
"September"	131	675	7	--	142	229	162	108	20	7
"October"	97	539	--	48	140	189	124	16	22	--
"November"†	19	104	--	9	27	37	24	3	4	--
"December"	2	15	--	--	5	7	3	--	--	--
"January"‡	11	56	--	1	13	20	13	6	2	1
"February"‡	23	121	1	3	28	43	28	14	3	1
Total Southern Calif.	295	1,573	9	61	368	546	369	157	53	10
Percentage		100.00	.57	3.87	23.40	34.72	23.46	9.97	3.37	.64
Total California	365									
Baja California§										
"August"	572									
"September"	1,735									
"October"	1,514									
"November"	1,872									
"December"	661									
"January"	398									
"February"	483									
			SAMPLES LOST							
Total Baja Calif.	7,235									
Total	7,600									

* No samples; "September" used.
† No samples; "October" used.
‡ No samples; "September", "October", "December" used.
§ Preponderance of fish from Central Baja California (Cedros Island and San Sebastian Viscaino Bay).

TABLE 2. **Estimated Age and Year-Class Composition of the Sardine Catch for the 1965 Central Baja California * Interseason**

Lunar period	Catch		Numbers of fish in thousands by age-group and year-class						
	Tons	Estimated number	II 1963	III 1962	IV 1961	V 1960	VI 1959	VII 1958	VIII 1957
Baja California									
"March"	687	6,245	--	250	1,561	2,061	1,936	312	125
"April"	1,912	19,120	--	191	8,222	4,971	3,633	2,103	--
"May"	1,420	13,524	--	541	3,516	7,303	1,758	406	--
"May B"	645	5,609	--	729	2,356	1,739	785	--	--
"June"†	464	4,035	--	524	1,695	1,251	565	--	--
"July"	807	7,017	351	2,807	3,228	631	--	--	--
"August"‡	1,473	14,029	11,785	1,122	1,122	--	--	--	--
Total	7,408	69,579	12,136	6,164	21,700	17,956	8,677	2,821	125

* Includes Cedros Island only—7,072 tons from northern and southern Baja California not sufficiently sampled. Includes 2,305 tons landed at Ensenada and 4,767 tons at Puerto Adolfo Lopez Mateos.
† No samples, "May B" and "July" data used.
‡ Only 1 sample, "May B", "July" and "August" data used.

Landing operated during the season, and in September the price of sardines increased from $65 to $75 a ton.

Twenty-nine large purse seiners, and 23 small purse seiners and lampara boats fished exclusively in southern California. Two other large purse seiners from Monterey joined the southern California fleet during the season. One cannery in Oxnard and four in the Los Angeles area processed fish. The sardine price was raised from $65 to $75 a ton shortly after the season opened in September.

The sardine industry in Baja California has been processing a greater portion of the Pacific coast sardine catch in recent years. Fishing is permitted throughout the year in this area. For purposes of comparison with southern California landings we have divided the years into season (September 1–March 1) and interseason components (Table 2).

Season landings in the Ensenada, Cedros Island, and Puerto Adolfo Lopez Mateos areas amounted to 7,235 tons, with interseason landings contributing 14,480 more. This represents a decrease of 12% from the 1964–65 period landings of 24,675 tons.

Catches of sardines in the Ensenada area were insignificant. The bulk of sardines processed at Ensenada came from San Sebastian Vizcaino Bay. Six canneries operated in the Ensenada area, one on Cedros Island, and one at Puerto Adolfo Lopez Mateos. The domestic demand for canned sardines was good, and the price fluctuated very little with $40 per ton being the average. There also was a good demand for fresh sardines in Mexican and United States markets. In the United States they were used primarily for bait.

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FOOD OF THE JACK MACKEREL, *TRACHURUS SYMMETRICUS*[1]

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California Department of Fish and Game

A food study of jack mackerel *Trachurus symmetricus* was carried out on samples taken during part of 1950, most of 1951 and part of 1952. Simultaneous plankton tows were taken at the time of sampling.

Jack mackerel were selective feeders. Over 90% of the food in the stomach samples consisted of copepods, pteropods and euphausiids.

Little correlation was noted between plankton samples and stomach contents.

Only limited competition appears to exist between jack mackerel and sardines.

INTRODUCTION

Jack mackerel, *Trachurus symmetricus*, became an important commercial species in California during the 1947–48 season, and biological studies on the species were instituted by me shortly after. This was at a time when the sardine fishery had begun its decline, and jack mackerel demand, as a cannery fish, increased. This study was terminated prematurely by my transfer to another project, and the work was not published at the time. Continued interest in this species as well as others studied by the California Cooperative Oceanic Fisheries Investigations, makes it desirable that the results of the study be published at this time.

Jack mackerel are found from the Gulf of Alaska to Cape San Lucas, Baja California, and as far as 1,300 miles offshore. The population is large and has been estimated to comprise between 2.1 to 4.8 million tons of fish (Ahlstrom, 1968).

METHODS

Food studies were initiated in 1950, when jack mackerel stomachs were collected during two cruises made by the M.V. *Yellowfin* during November and December. Additional stomachs were obtained from all *Yellowfin* cruises made during 1951. Samples were taken during all months of the year except May, June, and July. Samples also were obtained in April, August, and September 1952. Sampling was widespread off southern California, and the waters of the northern half of Baja California were well sampled. Jack mackerel were collected by throwing explosives into a school and retrieving the stunned or dead fish. All collections were made at night.

A few additional samples were taken during the day by beach seining and aboard a purse seiner in order to determine if jack mackerel utilize similar food organisms at night and during daytime hours. Since no particular difference was noted, analysis of these samples has been included with the others.

[1] Accepted for publication December 1970.

A vertical plankton tow was made at each station at which jack mackerel were collected. Identification of plankton is as complete as possible as far as jack mackerel food species are concerned. On those forms which occurred only in plankton samples and not in stomach contents, identification seldom was carried to genus, and often not beyond order (e.g. Copepoda, Isopoda). This procedure follows Savage (1931), and is satisfactory for the investigation's purposes. Data from the plankton tows are given, as well as the stomach analysis.

In all, 150 fish were collected and stomachs preserved in 5% formalin. The stomach, intestines and esophagus were all dissected and the contents examined under a dissecting microscope. All identifiable food items were numerated and recorded. Seventy-three had empty stomachs, while the remaining 77 fish had some food in their stomachs.

RESULTS

Most jack mackerel food items may be classified as macroplankton. In general, this species selects its food which is composed chiefly of larger planktonic animals. Over 90% of all food consisted of copepods, pteropods, *Limacina* sp. and euphausiids, predominately *Euphausia pacifica* Table 1).

TABLE 1. **Planktonic Food Items Obtained in Jack Mackerel Compared with Composition of Plankton Samples at Localities of Capture.***

	Total number taken in all stomachs	Number of stomachs containing items	Average number per stomach containing food	Percentage of total food items by number	Percentage of plankton sample containing item
Crustacean					
Copepoda	2,240	7	29.1	33.4	100
Euphausiacea	1,803	15	23.4	26.9	38
Amphipoda	215	14	2.8	3.2	25
Decapoda larvae	66	14	0.9	1.0	93
Isopoda	31	2	0.4	0.5	4
Ostracoda	15	3	0.2	0.2	8
Cladocera	4	2	0.1	0.1	54
Cumacea	3	1	<0.1	<0.1	10
Stomatopoda larvae	1	1	<0.1	<0.1	2
Mysidacea	--	--	--	--	40
Mollusca					
Pteropoda	2,005	11	26	29.9	94
Scaphopoda	7	1	0.1	0.1	--
Squid larvae	1	1	<0.1	<0.1	--
Post-larval Lamellebranchiata	1		<0.1	<0.1	40
Protozoa					
Foraminifera	78	1	1.0	1.2	56
Diatoms	2	1	0.1	<0.1	88
Tintinnids	4	1	<0.1	0.1	4
Other					
Fish larvae	187	5	2.4	2.8	38
Annilida larvae	33	2	0.4	0.5	60
Invertebrate eggs	11	1	0.1	0.2	4

* 77 of 150 stomachs analyzed contained food.

A comparison of plankton samples and items in stomachs indicated jack mackerel are generally particulate and selective feeders. However, they may at times, especially with small copepods, feed by filtering. Only a small portion of the organisms present in the plankton samples were found in any given stomach while, in some cases, particular

organisms were in much greater abundance in stomachs than would be expected after looking at the plankton samples. Simultaneous plankton tows revealed other organisms in large abundance which were not present in the stomach contents. On occasion, euphausiids (as many as 360 in one stomach) were the only organisms present in stomachs, while plankton samples produced few euphausiids. Nevertheless, some of the larger euphausiids may have avoided the plankton net.

Numerically, crustaceans made up 65% of all food and non-crustacean organisms made up 35% of the stomach contents. There were 6,706 organisms in jack mackerel stomachs examined. Copepods (33%) pteropods (30%) and euphausiids (27%) were the most abundant, accounting for 90% of all food items (Table 1). While copepods were the most numerous organisms present in stomachs, euphausiids appeared to be the most significant food item since they accounted for approximately 70% by volume of organic matter. Large copepods and pteropods comprised most of the remaining 30%.

Observations were made at the Hermosa Aquarium of jack mackerel feeding behavior. Small pieces of squid, less than $\frac{1}{4}$ inch in length, were dropped into a tank containing jack mackerel. The fish swam through the small cloud of food as it sank, selecting and eating a piece at a time. As a fish swam through the food, it would take one to three pieces then turn, go through again, and repeat the procedure. Thin strips up to 3 inches in length and about $\frac{1}{2}$ inch wide were dropped into the tank. The smaller fish were unable to handle these, but larger fish about 12 inches long ate them, taking one end in their mouths, and gradually working the whole piece down, as a fish might eat a worm. None of the fish would touch food which dropped to the bottom of the tank.

Observations also were made on board ship. It proved easy to get jack mackerel to take feathered or other artificial lures and cut bait. These observations substantiate the hypothesis that these fish feed selectively.

JACK MACKEREL-SARDINE COMPETITION

The jack mackerel food study was conducted partly to determine if this species competed for food with Pacific sardines, *Sardinops caeruleus*. The two species often school together, and spawn partly in the same waters off California's coast. We needed to know if they were competitive for their nutrition.

Competition for food appears to be moderate; some apparently exists between smaller fish for small copepods. Over 90% of the jack mackerel diet consists of euphausiids, large copepods, and pteropods; while the food of sardines consists of almost 90% small crustaceans with small copepods accounting for about 74% of the total organic matter (Hand and Berner, 1959; Radovich, 1952). On the basis of volume, euphausiids are by far the most significant jack mackerel food, making up about 70% of its diet with large copepods and pteropods constituting most of the remaining 30%. Euphausiids, account for only about 5% of the total food of sardines, and pteropods are eaten only in insignificant amounts.

Very little correlation could be found between stomach contents of jack mackerel and simultaneous plankton tows, but a strong positive correlation was shown between the stomach contents of sardines and plankton tows (Hand and Berner, 1959); this demonstrates the selectivity of jack mackerel feeding and predominate filter feeding habits of sardines. There appears to be little direct competition for food between the two species. However, it does exist at times. Ahlstrom (pers. comm.) states that while sampling sardines he frequently saw them gorged with euphausiids, which could only have happened by selective feeding.

ACKNOWLEDGMENTS

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FOOD HABITS OF WHITE STURGEON, *ACIPENSER TRANSMONTANUS*, IN SAN PABLO AND SUISUN BAYS, CALIFORNIA[1]

by

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The diet of white sturgeon is described based on an examination of the contents of 355 stomachs. Benthic invertebrates dominated the diet, with several species of clams being the most consistent important item. Barnacles, crabs and shrimp were important at times, but annelids were seldom eaten even though they are numerous in the area. Seasonally herring eggs were a major food, and several species of small fishes were sometimes eaten.

INTRODUCTION

In 1964, the sturgeon fishery in California's Sacramento-San Joaquin River estuary received a tremendous boost when it was discovered that using shrimp as bait would catch sturgeon. Yearly party boat catches jumped from 3 sturgeon in 1963 to 2,400 in 1967. The private boat fishery is probably keeping pace with the expansion.

The sturgeon in this water system have historically been overfished commercially (Pycha, 1956). Consequently, the California Department of Fish and Game initiated several studies to learn more of their life histories and angler exploitation to provide information necessary to manage the fishery. Among the studies was this survey of the sturgeon's food habits.

All of the fish sampled were caught by party boat anglers in either San Pablo Bay or the Carquinez Strait-Lower Suisun Bay area. Kelley (1966) describes these areas in some detail.

Schreiber (1960) and Radtke (1967) have described the diet of juvenile sturgeon collected in the Sacramento-San Joaquin Delta, but this is the first description of the diet of larger sturgeon from this river system.

METHODS

Sampling commenced in April of 1965 and ended in November of 1967. All of the samples were taken by a party boat skipper from fish caught by anglers on his boat. The entire alimentary tract was removed and frozen.

Laboratory analysis consisted of separating, counting and determining the volume by water displacement of the food organisms. Only material from the esophagus and stomach was examined as once the food got through the stomach, it was not identifiable.

The data were stratified by season and area. The areas were San Pablo Bay and the Carquinez Strait-Lower Suisun Bay region.

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RESULTS

San Pablo Bay

Clams were the most consistent important item in the 213 stomach samples collected in San Pablo Bay (Table 1). Several species as a group occurred in a third or more of the stomachs in all seasons, with their contribution to total food volume ranging seasonally from about 12 to 41%.

TABLE 1. **Esophageal and Stomach Contents of White Sturgeon Caught by Anglers in San Pablo Bay.**

Food item	Winter (49 fish)		Spring (90 fish)		Summer (35 fish)		Fall (39 fish)	
	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage
Crustaceans								
Shrimp								
Crago sp.	3.1	30.6	3.1	38.9	6.8	40.0	6.9	28.2
Palaemon macrodactylus	2.0	12.2	--	--	0.2	5.7	0.1	2.6
Unidentified	3.4	4.1	--	--	--	--	1.5	2.6
Isopods *Synidotea* sp.	3.1	6.1	0.3	11.1	4.6	34.3	*T	5.1
Amphipods (unidentified)	0.1	2.0	0.1	6.7	--	--	7.7	7.7
Barnacles *Balanus* sp.	3.4	4.1	0.9	4.4	44.1	25.7	--	--
Crabs								
Rhithropanopeus harrisii	28.6	51.0	0.8	8.9	0.4	11.4	12.1	30.8
Cancer magister	0.9	2.0	--	--	1.5	2.8	31.7	12.8
Hermit (unidentified)	--	--	--	--	--	--	0.4	2.6
Annelids								
Polychaete *Nereis* sp.	1.7	2.0	--	--	--	--	--	--
Nematode	--	--	T	2.2	--	--	--	--
Molluses								
Clams *Gemma gemma*, *Macoma* sp., *Tapes semidecussata* unidentified remains	14.4	34.7	11.8	78.9	40.9	57.1	32.9	61.5
Mussel *Mytilus* sp.	0.4	4.1	2.6	3.3	0.2	8.6	--	--
Snail (unidentified)	0.1	2.0	0.3	6.7	1.1	11.4	0.1	2.6
Fish								
Striped bass *Morone saxatilis*	3.4	4.1	--	--	--	--	--	--
Starry flounder *Platichthys stellatus*	8.9	6.1	1.1	2.2	--	--	--	--
Goby	3.4	2.0	--	--	--	--	0.4	5.1
Herring *Clupea harengus pallasi*	--	--	T	1.1	--	--	--	--
Unidentified fish remains	2.5	4.1	0.1	2.2	--	--	6.0	2.6
Herring eggs *Clupea harengus pallasi*	20.5	18.4	78.9	46.7	--	--	--	--
Plant material	--	--	T	1.1	--	--	--	--
Empty	--	14.3	--	5.5	--	5.7	--	12.8
Total	99.9	--	100.0	--	99.8	--	99.8	--

* T = Trace.

Other items made a less consistent but seasonally more important contribution than clams. A crab, *Rhithropanopeus harrisii,* made up nearly a third of the diet in the winter, and another crab, *Cancer magister,* contributed a similar percentage in the fall. Barnacles constituted about 44% of the food in the summer. Eggs of the herring, *Clupea harengus,* made up about a fifth of the diet in the winter and four-fifths in the spring.

Several species of fish composed about 18% of the diet in the winter and about a third as much in the fall.

Shrimp consistently occurred frequently (28-40% of all stomachs) but never contributed more than 7% of the total volume.

Suisun Bay and Carquinez Strait

Clams were also the most consistent important item in the 142 stomachs collected in this area (Table 2). Here, however, they were a significantly larger proportion of the total food volume than in San Pablo Bay.

Other items making major contributions to total food volume seasonally were barnacles in the spring and summer, crabs (*Rhithropanopeus harrisii*) in the winter and spring, and several fish species in the spring.

Shrimp again consistently occurred frequently. They contributed a somewhat greater percentage to total food volume than in San Pablo Bay. Also, oriental shrimp (*Palaemon macrodactylus*) made a more important contribution than in San Pablo Bay.

TABLE 2. **Esophageal and Stomach Contents of White Sturgeon Caught by Anglers in Suisun Bay and Carquinez Strait.**

Food item	Winter (15 fish)		Spring (59 fish)		Summer (27 fish)		Fall (41 fish)	
	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage	Volume percentage	Frequency percentage
Crustaceans								
Shrimp								
Crago sp.	4.9	26.7	6.9	47.5	7.6	31.5	3.2	17.1
Palaemon macrodactylus	7.5	13.3	0.3	5.1	1.1	6.3	1.7	9.8
Neomysis sp.	--	--	*T	1.7	--	--	--	--
Unidentified	2.6	6.7	--	--	--	--	--	--
Isopods *Synidotea* sp.	1.5	20.0	1.6	22.0	9.5	17.2	0.5	14.6
Amphipods (unidentified)	--	--	T	1.7	T	1.6	--	--
Barnacles *Balanus* sp.	T	6.7	10.9	13.5	29.1	21.2	5.4	12.2
Crabs *Rhithropanopeus harrisii*	27.4	40.0	10.3	16.9	0.4	4.7	3.1	4.9
Annelids								
Polychaete *Nereis* sp.	--	--	T	3.4	--	--	--	--
Molluses								
Clams *Gemma gemma*, *Macoma* sp., *Tapes semidecussata* unidentified remains	44.2	53.3	21.1	50.8	40.7	46.5	77.0	75.6
Mussel *Mytilus* sp.	0.6	13.3	--	--	--	--	--	--
Fish								
Striped bass *Morone saxatilis*	--	--	17.5	1.7	--	--	2.3	2.0
Starry flounder *Platichthys stellatus*	--	--	11.4	1.7	--	--	6.8	2.0
Anchovy *Engraulis mordax*	--	--	4.0	1.7	0.2	0.8	--	--
Midshipman *Porichthys notatus*	--	--	--	--	8.2	0.8	--	--
Staghorn sculpin *Leptocottus armatus*	--	--	0.1	1.7	--	--	--	--
Unidentified fish remains	3.8	20.0	12.9	5.1	3.2	4.7	--	--
Herring eggs *Clupea harengus pallasi*	7.5	6.7	2.9	1.7	--	--	--	--
Plant material	--	--	--	--	T	0.8	--	--
Empty	--	6.7	--	15.2	--	7.1	--	1.7
Total	100.0	--	99.9	--	100.0	--	100.0	--

* T = Trace.

DISCUSSION

As expected, benthic invertebrates dominated the diet of sturgeon. The kinds of organisms eaten are qualitatively similar to the invertebrate fauna found in this region (Ganssle, 1966; Painter, 1966). The principal exception is annelids, which are numerous in the area but seldom eaten.

The marked seasonal variation in the consumption of barnacles and crabs presumably reflects variations in availability, but the factors affecting availability are not clear. For example, Ganssle (unpublished data) caught numerous *Cancer magister* in both the summer and fall of 1964 in San Pablo Bay, yet they contributed little to the sturgeon's diet in summer. The irregular seasonal occurrence of significant amounts of fish in the diet is also difficult to interpret.

The differences in diet between the two areas primarily reflect the geographical distribution of prey related to salinity. The primary examples are the more marine species (e.g., *Cancer magister* and herring) occurring principally in San Pablo Bay.

Since shrimp are used as bait, their contribution to diet is presumably biased. Both *Crago* and *Palaemon* are used as bait, so the differences in the relative contribution in the two areas suggest that much of the shrimp eaten is not bait.

This study points up the importance of shallow areas within the estuaries for the production of food for the sturgeon. Nearly all the food items found are numerous in the mudflat communities, and sturgeon are observed in great numbers in the mudflat areas. It is unlikely the present sturgeon population could sustain itself if these areas were taken out of production by landfills.

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NIGHTTIME ARTIFICIAL AERATION OF PUDDINGSTONE RESERVOIR, LOS ANGELES COUNTY, CALIFORNIA[1]

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Puddingstone Reservoir has a yearlong warmwater fishery, but a trout fishery only during the cooler months. The reservoir was artificially destratified during 1968 using a nighttime air injection schedule in an attempt to lower the water temperature and eliminate an oxygen deficit; thereby creating suitable summer trout habitat. Nighttime air injection maintained suitable oxygen levels, but increased minimum temperatures to intolerable levels. A system of hypolimnion aeration is recommended whereby both adequate oxygen and temperature for trout will be maintained at all times of the year.

INTRODUCTION

Artificial destratification of eutrophic reservoirs is beneficial since it increases fish habitat and available food, and reduces the probability of oxygen depletion. Continuous destratification, however, increases the heat budget and eliminates the cold hypolimnetic water (Fast 1968). The hypolimnetic temperature of warmwater reservoirs is generally suitable for trout, but this stratum is normally devoid of dissolved oxygen during the summer. Artificial destratification eliminates this oxygen deficit, but with the result that the entire lake has about the same temperature as the surface water before destratification began. In most southern California reservoirs these temperatures are too warm for trout.

These reservoirs presently support yearlong warmwater fisheries and coldwater fisheries only when surface temperature is less than 24 C. If oxygen could be added to the hypolimnion without greatly increasing its temperature, or if the average temperature could be reduced sufficiently by destratification, trout could survive throughout the year. Development of these reservoirs for all-year catchable trout fisheries would greatly increase recreational potential near populous areas.

Puddingstone is a typical southern California warmwater reservoir. It has 200 surface acres, receives heavy angling pressure and is located near metropolitan Los Angeles. The Los Angeles County Department of Parks and Recreation manages Puddingstone for multiple use. Catchable trout are planted by the California Department of Fish and Game during the cooler months, usually from October to April. The Department of Fish and Game felt that an all-year trout fishery would be especially desirable in this reservoir. Whalls (1968), therefore, pro-

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posed to create such a fishery by reducing the average water temperature through a method that relied upon nighttime air injection. He initiated and designed the aeration program used.

MATERIALS AND METHODS

Pre-destratification monitoring of Puddingstone Reservoir temperature and dissolved oxygen began during April 1967. Temperatures were measured weekly at 1 meter intervals from the surface to the bottom. Oxygen was measured weekly at several depths. These measurements continued through August 1969.

The Department of Parks and Recreation installed a Jaeger rotary air compressor (260 c.f.m. @ 100 p.s.i.) during 1968, following recommendations of the Department of Fish and Game. An air distribution system similar to the diffuse system described by Fast (1968) was used. Over 1,200 ft of 2-inch diameter pipe extended to near the deepest point in the reservoir. The last 200 ft were perforated with 400, $\frac{1}{16}$-inch diameter holes and were bent at a 45-degree angle to the main line.

Air injection began on March 13, 1968, and was injected from 2000 to 0800 hours daily until July 8, 1968. From July 8 until August 14, 1968, air was injected from 2100 to 0500 hours daily. From August 14, 1968, through December 23, 1969, the latter schedule was supposed to be maintained, but malfunctions resulted in only 434.1 hr of operation, the seasonal distribution of which is unknown.

RESULTS AND DISCUSSION

During August 1967 temperatures ranged from 13.3 C (bottom) to 27.2 C (surface) with a 22.5 C mean (Figure 1). This is typical during years of normal stratification. During the period of air injection in 1968 the thermal regime was greatly altered. Temperatures ranged from 25.0 C to 25.6 C with a 25.5 C mean. This clearly indicates a significant increase in the heat budget as well as the minimum temperature. Although the 1968 yearly maximum temperature was less than the 1967 yearly maximum, this may have been due to factors other than air injection. In any event, the minimum water temperature was greater than trout can tolerate for extended periods. Temperatures during August 1969 ranged from 13.9 C to 27.2 C with a 23.0 C mean. This is very similar to the 1967 condition and indicates that not much air was injected during 1969.

Dissolved oxygen concentrations ranged from a 0.0 mg/liter minimum at the bottom to near saturation at the surface during 1967 (Figure 1), as is typical of southern California reservoirs. Air injection during 1968 dramatically changed the oxygen regime. Minimum oxygen values during 1968 seldom fell below 6.0 mg/liter. This is adequate for trout but of course the temperatures were not. Oxygen values for 1969 were similar to those of 1967, although concentrations near the bottom were slightly greater.

These results indicate that nighttime air injection during thermal stratification will not create adequate yearlong trout habitat in southern California reservoirs. The most likely means of achieving this ob-

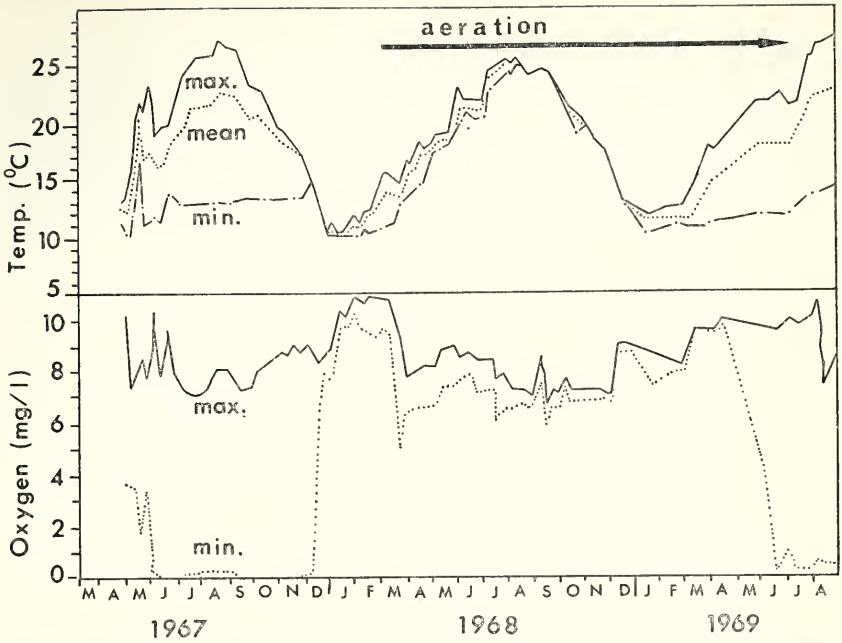

FIGURE 1. Temperature and oxygen conditions associated with the artificial aeration of Puddingstone Reservoir.

jective would be through aeration of the hypolimnion without thermal destratification. This would result in adequate oxygen concentrations without intolerable increases in temperature. Fast (1968) describes devices for aerating the hypolimnion without producing thermal destratification. Barnhardt (1967) discusses the artificial aeration of the hypolimnion of Wahnback Reservoir where oxygen values were increased from near zero to over 5.0 mg/liter. Fast (unpublished data) was able to increase hypolimnion oxygen concentrations in a small Michigan lake from 0.0 mg/liter to over 11.0 mg/liter using a new areator design. We recommend, therefore, that hypolimnion aeration be used in Puddingstone Reservoir to produce the desired changes in hypolimnion oxygen content necessary to create a yearlong trout fishery.

ACKNOWLEDGMENTS

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NOTES

A SECOND RECORD OF THE SCYTHE BUTTERFLYFISH, *CHAETODON FALCIFER*, FROM CALIFORNIA

The type specimen of *Chaetodon falcifer* was speared on November 16, 1954 at a depth of 33 m at Guadalupe Island, off Baja California, Mexico by Andreas B. Rechnitzer. The species was subsequently described from that specimen by Hubbs and Rechnitzer (1958). Since then, seven other individuals have been recorded (Freihofer 1966). R. Kiwala collected one alive in Cabo San Lucas submarine canyon at 53 m on February 20, 1967, which was not recorded, and the species was observed from the submersible, *Deepstar*, between 100 and 150 m in the same canyon. One of the specimens reported by Freihofer was taken at Catalina Island on September 22, 1965 at a depth of 13 m.

On November 16, 1970 the first *Chaetodon falcifer* recorded from the mainland of California was captured near La Jolla at a depth of 21 m by the authors. The animal was approximately 135 mm in length, about the same size as the type specimen. There can be little doubt as to the identification of this distinctive species.

FIGURE 1. *Chaetodon falcifer:* On display at T. Wayland Vaughan Aquarium Museum, SIO. *Photo by L. Ford.*

The collection was made on an isolated rocky reef ½ mile NW of the La Jolla Cove at lat 32°51′3.5″N and long 117°16′6.6″W, locally known as "God's Rock." The reef rises to about 18 m from a depth of 23–25 m and is surrounded by a coarse sand substrate. The water temperature was 16.2 C with no appreciable thermocline. The *Chaetodon* was first observed in a short, rocky tunnel about 4 ft x 2 ft and swam directly to a second similar hole upon pursuit where it was netted. It is presently on live display at the T. Wayland Vaughan Aquarium-Museum and ultimately will be placed in the permanent SIO collection.

Despite the large number of dives made in this area by SIO personnel, this is the only individual of *C. falcifer* ever observed here. Considering the separation in time and space of the previous California record, it seems most likely that both individuals represent strays and that California is not within the primary range of the species. It is probable that the shallower occurrences of the species at the limits of the range represent poleward emergence of a deeper-water tropical form.

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———*Robert S. Kiwala and Ronald R. McConnaughey, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California 92037. Contribution from the Scripps Institution of Oceanography, new series. Accepted for publication March 1971.*

A SEI WHALE, *BALAENOPTERA BOREALIS*, FEEDING ON PACIFIC SAURY, *COLOLABIS SAIRA*

On August 18, 1969 a sei whale was captured approximately 85 miles west of Point Reyes, California (lat 37°50′ N, long 124°45′ W) by the *Dennis Gayle*, a commercial whaler. The vessel had previously been conducting saury research under charter to the National Marine Fisheries Service (NMFS) whose biologists were still aboard the vessel when the whale was sighted and killed.

During a 2½ hr period prior to its capture, the whale was often sighted in the vicinity of large schools of saury "breezing" in surface waters. Twice we witnessed an apparent attack. On both occasions the whale, initially sighted about 10 m beneath the surface, approached the surface school at a shallow angle of ascent while maintaining about 3-knot swimming speed. Once beneath them, the whale rolled to the surface amid the rapidly dispersing sauries, sounded and then disappeared.

On August 19, 1969, about 13½ hr after capture, the whale was rendered at shoreside processing facilities. It was a female and measured 13.3 m (43.9 ft) TL. The stomach appeared to be filled to capacity with sauries although a small quantity of unidentified euphausiids also was present. The sauries ranged from 6 to 29 cm FL. The aggregate weight of the ingested sauries was estimated around 227 kg (500 lb.). About 45 kg (100 lb.) of sauries which occupied the upper stomach area appeared fresh and showed no signs of digestion while the remaining specimens displayed early stages of digestion in the central stomach area and advanced digestion in the lower stomach area.

Literature on the feeding habits and food of Pacific sei whales is limited to Asiatic and extreme north Pacific waters. In Nemoto's (1959) extensive report on baleen whales, the sei is described as a swallowing (gulping), skimming, and somewhat opportunistic surface feeder. In order of preference, major foods are copepods, euphausiids, swarming fishes (Pacific saury being a major item when available), and squid. Unpublished stomach content data recently collected by NMFS Marine Mammal Laboratory, Seattle (Dale Rice, pers. comm.), indicate euphausiids, anchovy, and Pacific saury are the three major food items of sei whales off California. The stomach content analysis indicates that saury may be a substantial food source for sei whales in California waters.

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Charles D. Gill and Steven E. Hughes, National Marine Fisheries Service, Exploratory Fishing and Gear Research Base, Seattle, Washington. *Accepted for publication, February 1972.*

THE FOX SQUIRREL (*SCIURUS NIGER*) IN VENTURA COUNTY

The fox squirrel of the eastern United States (*Sciurus niger*) has been introduced into a number of urban areas in California. Usually the squirrels remain in the vicinity of the original introduction, but they occasionally spread to the surrounding countryside. In Ventura County fox squirrels are established in the agricultural land east of Ventura and Oxnard (Ingles, 1965; McLean, 1963). This report is based on observations made by Wolf in Ventura County during 1968, 1969, and 1970.

Fox squirrels in Ventura County differ from the native gray squirrel (*Sciurus griseus*) in having orange or cinnamon colored ventral surfaces and tail margins; corresponding areas on gray squirrels are white. A key difference is the presence of only four cheek teeth in the upper jaw of the fox squirrel, while the gray squirrel has five.

Fox squirrels inhabit the coastal plain from near Oxnard north to the mouth of the Santa Clara River and eastward to the vicinity of Camarillo; the Simi Valley as far east as the town of Simi; and the Santa Clara River Valley as far as Fillmore. There are unconfirmed

reports of fox squirrels at Lake Casitas and Lion Canyon Campground, and in Santa Barbara County near Carpinteria.

In Ventura County fox squirrels are found near walnut and orange orchards, in tall eucalyptus trees which were planted many years ago as windbreaks. The eucalyptus trees provide shelter and nest sites for the squirrels, while the orchards furnish the primary food supply. Squirrels eat green walnuts during the summer and continue feeding on mature nuts through the fall. After the fall harvest very few nuts are left, and after mid-December the squirrels rarely enter the orchards. Squirrels near orange groves feed on the fruit throughout the year. They bite an opening in the peel and remove the fruit through the hole, leaving a characteristic hollow rind.

Captive squirrels were fed walnuts and oranges, and the amounts of each consumed were noted. Squirrels fed walnuts exclusively ate about $\frac{1}{10}$ lb. per day; about $\frac{1}{10}$ lb. was eaten each day by those fed only on oranges. Simple extrapolations, using the wholesale price of each crop, suggest that each squirrel probably eats less than $20 worth of nuts and/or oranges each year. At the present low population level, damage does not appear to be serious. In fact, most ranchers are not unhappy about the squirrels on their land, and many landowners find them attractive and interesting.

In addition to walnuts and oranges, fox squirrels were seen eating avocados, strawberries, and tomatoes, where available. In mid-winter they were observed feeding on eucalyptus pods. The outer part of the pod was chewed off, apparently to reach the small seeds inside. To our knowledge, no other California mammal uses the introduced eucalyptus for food.

Population estimates were developed by counting the number of squirrels observed per 100 yards of windbreak tree row. There were from 0.1 to 2.0 squirrels per 100 yards, with an average of 0.85, at eight different localities where such counts were made. One additional locality had 35.0 squirrels per 100 yards, but was cleared for field crops in 1970; the squirrels are now gone.

The fox squirrel seems well established in Ventura County. Economic pressures are presently forcing changes in land use from the existing orchards to field crops or to suburban housing developments. The large eucalyptus trees and most of the walnuts and oranges usually are removed when this happens, and the squirrels are forced to leave. They may eventually occupy adjacent habitats such as oak woodland and riparian woodland, a shift which already may be happening if the report from Lake Casitas is confirmed. Since the native gray squirrel occupies such habitats, it will be interesting to see how the two species eventually interact.

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BOOK REVIEWS

The Ecosystem Concept in Natural Resource Management

Edited by George M. Van Dyne; Academic Press, New York and London, 1969; 383 p. $14.85.

Classical ecology, which often hasn't seen the ecosystems for the trees, seems to be giving way slowly to the conceptual excitement of new approaches. This book reflects the current dichotomy in the field. It grew from a symposium held at the annual meeting of the American Society of Range Management in 1968. It contains two types of contributions, which are in sharp contrast. The three chapters in the second section of the book, entitled "Examples of Research Development and Research Results Applying Ecosystem Concepts" illustrate the relatively new systems analysis approach at its best, based on reasonably adequate data gathered by highly organized field groups following a well-conceived research plan.

The chapter by Arnold Schultz on The Arctic Tundra develops an elegant hypothesis to explain lemming cycles in relation to the cycling of plant nutrients through the system. Significantly, some of the more important insights into the inner workings of the tundra ecosystem depended on carefully controlled field experiments in which segments of the system were isolated and manipulated, for example, by fertilizing the plants or by excluding the lemmings. The other seven chapters generally mine the vast ecological literature in various specific areas of interest to resource managers. They tend to be long on scholarly detail and short on new concepts and insights. It seemed to me they would be very useful to individual researchers in the various fields, as reference material, but of only passing interest to most resource managers. Fisheries resources are mentioned only briefly in passing.—*Alex Calhoun*

Eutrophication: Causes, Consequences, Correctives

Symposium under chairmanship of Gerard A. Rohlich; National Academy of Sciences, Washington, D.C., 1969; 661 p. $13.50.

California shares generously in the worldwide eutrophication problems, with foci at Tahoe, Clear Lake, Salton Sea, and in the Sacramento Delta. Lakes, rivers and estuaries all over the world are receiving more and more nutrients from expanding human populations and their agricultural and industrial activities. The gravity of this situation prompted the National Research Council to form a Planning Committee on Eutrophication in 1965. Anyone grappling with such problems will applaud the resulting worldwide symposium in 1967, and this 1969 book, which summarizes a wealth of background information on the enrichment of aquatic ecosystems.

The first three groups of contributions outline the situation in various parts of the world. The discussions are supported by extensive illustrative data and bibliographies. The responses of various kinds of aquatic plants and animals to environmental enrichment are discussed next in the context of indicator organisms. Fishery biologists will enjoy the paper by Brooks on the selective grazing of zooplankters by fishes, and the one by Larkin and Northcote on fish as indicators of eutrophication. Administrators who are grappling with immediate problems should find the nine chapters on preventive and corrective measures valuable, even though they are not apt to find much in the way of new solutions, or much on the important economic aspects of the old approaches. They will, however, find ample confirmation that it is better to keep nutrients out of aquatic ecosystems in the first place, than to try to get rid of them after they are introduced.

Drawing all this background information and all these excellent lists of references together was a great first step. But what's the next step? After finishing the book and rereading the recommendations in the introductory chapter, I wondered if this massive problem is getting the kind of attention it needs. There are so many recommendations from the symposium and so little indication of responsibilities for carrying them out. It's so easy to say what someone else should be doing! Let's hope the National Research Council recognizes an obligation to go beyond data gathering and recommendations to considerations of implementation. Perhaps the need for further action needs dramatizing in some constructive manner. A second symposium, of a very different sort, based on a representative series of well documented case studies in the United States holds interesting possibilities. It could highlight eutrophication as a national problem and, at the same time, define the issues more clearly, expand the limited information on solutions, pinpoint critical research needs, and do a lot of the educating recommended by the 1967 symposium.—*Alex Calhoun*

How to Attract, House and Feed Birds

By Walter E. Schultz; The Bruce Publishing Company, New York, N.Y., 1970; 196 p., illustrated. $7.95.

This third edition was first published under the title *How to Build Birdhouses and Feeders*, and published secondly under the title *Bird Watching, Housing and Feeding*, all by the Bruce Publishing Company. The opening chapter discusses ecology today, man's responsibility to himself and the biotic community which surrounds him, and points out the economic importance of birds. Chapter two entitled "Bird Watching" provides helpful hints on how a beginner can get started birding, activities which can intrigue the beginners, how and where to find birds, how to identify birds, and plantings that attract birds. As the author said, "it is not the purpose of this book to explore all these allied activities in detail. However, the beginner should be aware of the possibilities of the hobby . . . . ." The emphasis of this book is placed on the three basic requirements of all wildlife: i Food, Chapter 3; ii Water, Chapter 4; and iii Shelter, Chapter 5. The author points out the essential items in a feeding program, describing ingredients needed to fill basic food requirements for insectivorous and seed eating birds. Illustrations and drawings of 18 feeders complete with material lists are very good for those of us who are less mechanically inclined. Ways of complementing a feeding program with a supply of fresh water is illustrated in an informative manner. The third requirement, shelter, is handled in equally a fine manner with hints on nesting materials, houses and nesting shelves for a number of species. Some helpful hints to provide protection for wintering birds, from predation, and the care of sick birds are useful to all birders with a backyard feeding program or those providing nest boxes for birds. A useful listing of reference books and national conservation agencies is provided.

The author failed to point out some problems concerning disease and parasites which can occur with a feeding program and steps which should be taken to prevent this or what should be done if it occurs.

Information provided in this book primarily applies to eastern species. However, much can be applied to western species and the book is a useful reference on "How to Attract, House and Feed Birds."—*Robert D. Mallette.*

Management of Lakes and Ponds (Second Edition)

By George W. Bennett; Van Nostrand Reinhold Co., New York, N.Y., 1971; xx + 375 p., illustrated. $15.95.

With a slight change in title from his first edition (Management of Artificial Lakes and Ponds) Dr. Bennett's revised text on lake and pond management appears as a welcome contribution to the fisheries literature. The deletion of the word "artificial" from the book's title represents less of a change in the subject matter than an attempt to free the title from its original restrictive implications. Like the first edition, it is primarily concerned with warmwater lakes and ponds; however, many of the concepts of fisheries management presented will apply in principle to other North American freshwater fisheries.

The second edition has been enlarged by some 92 pages, approximately 25% of which are new topics. The remainder represents expansion and updating of original material. The new material includes brief sections on natural and man-made lakes as aquatic habitats, creel census and fishing surveys, and catfish farming. The greatest expansion of material was noted in Chapter 6 (Theories and Techniques Management), Chapter 3 (Interrelationships of Fish and Lake Habitats), and Chapter 5 (Reproduction, Competition, and Predation). Only a few brief sections have not been carried over from the first edition. These include sections on sport fishing economics, and the status of sport fishing as a form of recreation, topics which now are easily deserving of a volume of their own. The references have been enlarged greatly to include much of the important literature on lake and pond management published from 1963 through 1969. In addition, many new references are cited which appeared prior to the publication of the first edition (1962). In several chapters the number of references has about doubled, a feature that has increased the utility of the book significantly.

While the same chapter organization has been followed in the new edition, I found improvements in the within-chapter organization and in the greater use of subheadings which tended to improve readability somewhat. A particularly welcome improvement was observed in the format of the references, which now include the title of the work cited. A small number of typographical errors were observed, primarily in the references; however, they should not present any particular difficulty to the reader.

Although the author states that this book is ". . . directed towards pond owners, fishermen, and fishery biologists . . ." its primary usefulness will remain for the student who uses it as an introductory text to the principles of warmwater fisheries biology and management. In this regard, it is a pleasant surprise to see the prompt appearance of this revised edition. There is a noticeable lack of up-to-date introductory texts in fisheries biology and management, and I believe this book will go a long way toward filling that void.—*Stephen J. Nicola.*

Fish and Invertebrate Culture: Water Management in Closed Systems

By Stephen H. Spotte; Wiley-Interscience, A Division of John Wiley and Sons, Inc., New York, N.Y., 1970; 160 p., illustrated. $8.95.

Fish and Invertebrate Culture is a misleading title for this book. Rather than being a classical text on fish culture, this book is almost completely dedicated to the description and use of various filters to maintain water quality in closed-system aquaria. Reproduction, feeding, and other life history aspects of rearing fish and invertebrates are not discussed. Nevertheless, the book is of value to those interested in rearing aquatic organisms. Both theoretical and practical methods of maintaining water quality are discussed. The book is divided into two parts: (Part I) Effects of Animals on Captive Water, containing chapters on biological, mechanical, and chemical filtration and the carbon dioxide system; (Part II) Effects of Captive Water on Animals, containing chapters on respiration, salts and elements, toxic metabolites, disease prevention by environmental control, and laboratory tests of water quality. The text is well illustrated and has very good descriptions of numerous filter systems. It explains why water quality is important and how the filters maintain good water quality.—*James W. Burns.*

How to Be a Survivor

By Paul L. Ehrlich and Richard L. Harriman, Ballatine Books, Inc., New York, N.Y., 1971, 207 p.

This book presents a plan to save spaceship earth from self destruction by its present dominant life form *Homo sapiens*. The book advocates that the 3.6 billion passengers on spaceship earth become crew members so that our spaceship may continue its journey without a disaster. In retrospect it is apparent that in the 10,000 years of human history there has never been a rational crew in charge of our spaceship so I have my doubts that we can act rationally at this late hour. The author's program urgently pleads for population control and the de-development of the over-developed nations coupled with semi-development of the underdeveloped nations. Global monitoring and resource regulation machinery would be put into operation to assure an optimum resource population balance.

Many ecologically sound ideas are presented to create a rational society to replace the current, consumptive, self-destructive American society. Many of the ideas are not new but the need for their immediate implementation is now so great that we can no longer put off the drastic measures required to make civilization last a bit longer.

Hopefully enough people will be inspired by this book to make the difference between survival and oblivion.—*Lee W. Miller*

A Book of Trout Flies

By Preston J. Jennings; Crown Publishers, Inc., New York, 1970, xvi + 190 p., illustrated in color and black and white. $7.50.

Preston Jennings', *A Book of Trout Flies*, originally published in 1935 is considered to be *the* classic and pioneering book on the identification and imitation of American trout stream insects.

The mayflies are discussed extensively. Life histories, measurements of adults, 1935 emergence dates on eastern streams, and the correct materials for tying imitations are given for each of the important mayflies—the Hendrickson, Quail Gordon, Green Drake, etc.

Additional chapters discuss the other insects important to the trout: the caddis, stone, and alder flies, ants and black gnats. There is a brief section on nymphs, variants, and minnows.

The final third of the book is a treatise on fly tying and fly tying materials. Jennings discusses trout vision and gives his views on tackle, wings, bodies, tails, hooks and fly tying equipment in separate chapters. He stresses the need for quality materials and indicates which materials are best.

The book is illustrated with color plates of the adult insects and their imitations. Black and white drawings are used for minnows and nymphs.

Historically, the book is interesting. Material and methods of fly tying have changed very little in 35 years. The question of whether wings are necessary on a fly still has not been answered. It is an excellent book with information for both the beginner and the expert.—*K. A. Hashagen, Jr.*

The Art of Tying the Wet Fly and Fishing the Flymph

By James E. Leisenring and Vernon S. Hidy, Crown Publishers, Inc., New York, 1971; 160 p., illustrated. $4.50.

This factual little book, originally published in 1941, is another of Crown Publishers, Inc. new, revised editions of classic fly fishing books.

Written by the late Jim Leisenring, this new edition has an introduction by Ernest Schweibert and three new chapters on "Fishing the Flymph" by Vernon Hidy.

The book is extremely easy to read. It consists of a series of chapters on fly tying equipment and materials. Throughout the book Leisenring stresses the need for quality materials, the need to duplicate as closely as possible the size, color, and texture of the natural when tying wet flies and nymphs. Chapters describing the spinning of bodies, working with wings, and the tying of a wet fly are clearly written and illustrated with photographs and excellent line drawings.

My one criticism of the book is with the photographs. They are not identified by number, and consequently, when referred to in the text, are difficult to locate. Once located, most prove to be dark and difficult to interpret.

The final three chapters describe the "Flymph"—a wingless artificial designed to imitate aquatic insects when they are no longer nymphs but not yet emerged adults —and how to fish it. Designed to take fish feeding just under the surface, the flymph is fished with light lines and fine leaders. The chapters describing this unique type of fishing nicely complement the preceding chapters on tying wet files and nymphs. —*Kenneth A. Hashagen, Jr.*

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